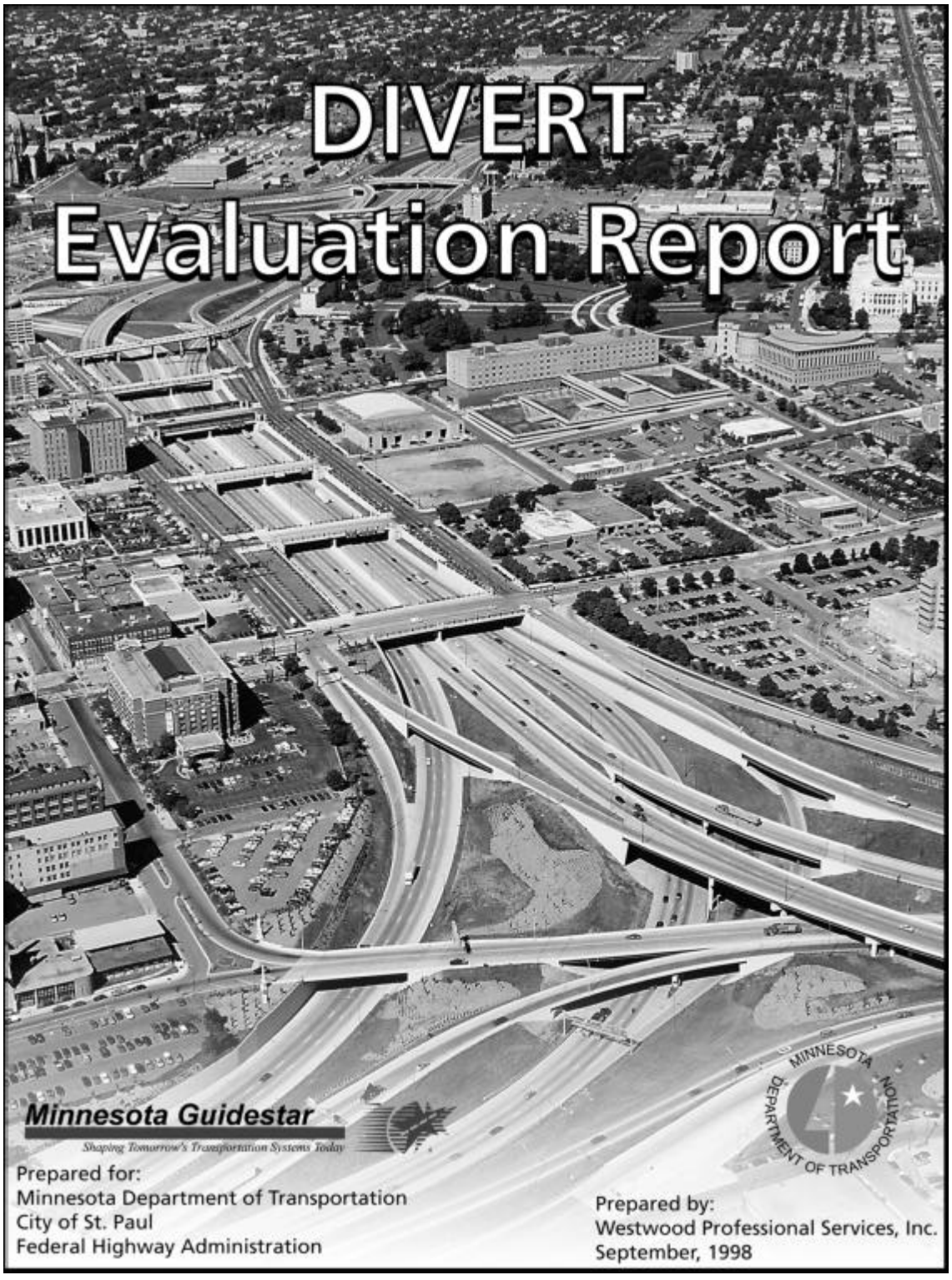

Prepared for:
Minnesota Department of Transportation
City of St. Paul
Federal Highway Administration

Prepared by:
Westwood Professional Services, Inc.
September, 1998

DIVERT
(During Incidents Vehicles Exit to Reduce Time)

EVALUATION REPORT

September 1998

Submitted to:

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1.0 EXECUTIVE SUMMARY

1.1 PROJECT CONCEPT

Two major freeways (I-94 and I-35E) come together in a common section in the vicinity of downtown St. Paul. The Minnesota Department of Transportation Office of Advanced Transportation Systems and the City of St. Paul jointly developed and deployed an incident management project under the acronym DIVERT (During Incidents Vehicles Exit to Reduce Time) to manage the effects of incidents on I-94 and I-35E. The goal of DIVERT is to provide management strategies during periods of freeway incidents by routing diverted traffic over City surface arterials in a planned, coordinated manner.

One of the major initiatives of the DIVERT project was to improve the joint management of freeway and city traffic through enhanced institutional cooperation between Mn/DOT and the City of St. Paul. This enhanced cooperation would allow the DIVERT objectives to be achieved through a three phased process of incident detection, route guidance and traffic signal control. In so doing, DIVERT links together two significant systems (Mn/DOT Freeway Management System and City of St. Paul central based traffic signal control system for its downtown network) which formerly had no linkages or interactions.

In the DIVERT concept, incident detection is achieved by having continuous access to freeway detector information from the Mn/DOT Traffic Management Center (TMC). Route guidance is achieved through three means: freeway changeable message signs (CMS) used to inform freeway motorists of an incident, static trailblazer route marker assemblies to help guide motorists along the arterial diversion routes and light-emitting-diode “blank-out” signs to guide motorists back to the freeway over alternate routes. Traffic signal control is achieved through a special download of diversion management timing plans to the field. The DIVERT system runs in the background to the main City central system, and 17 special incident timing plans reside within the DIVERT processor. When the operator initiates a timing plan change, the DIVERT system downloads an override command to the local intersections and then also downloads the selected plan. The selected plan is locally stored and executed at each of the divert arterial intersections during the declared incident management period.

1.2 PROJECT HISTORY

The project concept phase was initiated in late 1993. In mid-1994 the preliminary design was approved and the detail design/implementation phase began. The project was formally declared to be operational on December 9, 1996 and the operational test commenced a one and one-half year data collection and evaluation period. The formal evaluation data collection period ended on June 30, 1998.

While DIVERT was under development, Mn/DOT as part of a separate initiative completed geometric improvements and upgrades to the I-94/I-35E common section/Capitol Interchange area. This action greatly reduced the number of incidents in the DIVERT project area. During the one and one-half year operational test the DIVERT system was only turned on three times to manage incident based traffic congestion. One of these activations was significant (2 hours and 16 minutes); the other two activations were of short duration (15 minutes and 28 minutes). Due to staffing limitations at the City of St. Paul, the system is only operated Monday through Friday from approximately 8:00 a.m. to 4:30 p.m.

1.3 MAJOR EVALUATION FINDINGS

Several detailed evaluation findings are included throughout this report. Some of the major findings, which cover main themes of the project, are listed below:

- Freeway reconstruction activities in the I-94 and I-35E common section reduced the number of accidents in the area; this lessened the ability of the project to demonstrate its incident management service features.
- The project demonstrated a new level of interaction and communication between the Mn/DOT TMC and the City of St. Paul Traffic Division in their joint efforts to manage traffic in the St. Paul area. Even though the system was activated only three times, the TMC and City were able to establish lines of communication and processes for initiating system activation.
- The DIVERT demonstrated a successful integration of new signal control features with an inplace legacy system.
- The DIVERT system increased the capability of the inplace central control system. DIVERT added 17 new signal timing plans to the system and also provided the ability to instantly download the plans. The DIVERT project thus leveraged the previous investment in the central system, and extended the service life of the City's central control system.
- The project demonstrated effective use of the inplace City twisted pair copper communications system to transmit video images from arterial based cameras.
- The City of St. Paul has made extensive use of the new management tools in their everyday operation of the surface street network. In particular, these tools have been used for fine tuning signal operations and handling special event traffic in the downtown area.
- The implementation and shakedown period for this integrated system was significant and the complexity, timeline and dollar resources to successfully implement the project were underestimated by all project partners. From the beginning of the project to the initial deployment the acceptance criteria were not clearly delineated and adhered to. Therefore, the pre-operational test phase did not accurately determine if the system was ready to be declared operational. In the spring of 1997 Mn/DOT appointed a new project manager, Ben Osemenam, after the system had run for approximately half a year. The project manager reconvened the project team and established a new project management plan. Under this project management plan partner roles and deliverable criteria were clearly defined. From that point on the team was able to identify and solve the remaining technical issues of DIVERT thereby completing a successful project deployment.
- The use of portable traffic signs with cellular phone control proved to be a difficult part of the system integration and start up system operation. Guided by the project management team, the system designer and sign vendor worked together to identify a method to improve the reliability of the cellular communications control. As part of this technical solution, the sign vendor, ADDCO, Inc., changed out sign modem equipment, at no cost to the project, and reliable sign communications were achieved.
- At the request of the project manager, the project management team developed a plan to modify DIVERT and thereby continue to provide the major traffic management services of DIVERT as a permanent joint TMC-City effort. Therefore, the team was able to establish an ongoing DIVERT Legacy System. This is the first Minnesota Guidestar Operational Test Project to make the formal transition to permanent, legacy status.

1.4 DIVERT LEGACY SYSTEM

At the end of the evaluation data collection period, the agency partners met to determine the future support and operation of the DIVERT system. The group decided to move forward by retaining key DIVERT service features, but with some of the DIVERT system elements eliminated.

Incident detection: The automated incident/congestion detection module was eliminated. Throughout the operational test, this was a problematic element. The team selected a traditional TMC incident detection/notification process, as follows. When the TMC operators become aware of a "major" incident or congestion in the DIVERT area, the TMC operators - as part of their standard work scope for major incidents - will notify the St. Paul operator. With the high percentage of drivers with cellular phones, when a major incident occurs, the TMC (via the State Patrol scanner) will know of an incident quite quickly. With the agreed upon description of the threshold for when DIVERT would be activated, the team's expectation is that DIVERT would only be turned on a few times a year. Therefore, the TMC incident notification process would also only be invoked very infrequently.

Freeway signing: The portable message signs that were part of the operational test were not meant as permanent elements. By the end of 1998, at three of the four DIVERT portable changeable message sign locations new TMC overhead variable message signs will be implemented as part of separate TMC efforts. For these three locations the team decided to port the messages from the portable signs to the TMC signs. The turn on procedure would involve the St. Paul operator selecting the desired message and asking the TMC operator (who physically controls the sign) to turn on the message. In this manner, the City of St. Paul maintains decision control over the activation of diversion messages.

For the fourth DIVERT portable sign, the TMC does not have an overhead sign well placed to serve the DIVERT project, nor are there any firm plans now to have a sign in the DIVERT area. Therefore, no DIVERT message service will be provided for that direction.

City control elements: The City of St. Paul will continue to operate all DIVERT elements on its right of way (e.g., CCTV cameras and arterial "blank out" signs). Also, the City will continue to run the DIVERT central processor that downloads new traffic signal timing plans.

Operations: The agencies agreed that incident detection and notification will be conducted by the TMC and that sign decision and timing plan activation will be controlled by the City. The TMC will add the DIVERT procedures to its formal list of incident management tools in the St. Paul area. Also, on an ongoing basis, St. Paul will equip two system operators with pagers to ensure that TMC operators can reach a St. Paul operator in an incident situation.

Maintenance: Mn/DOT TMC will maintain the freeway element of DIVERT Legacy (the variable message signs) as part of their system-wide freeway sign maintenance program. The City will maintain the DIVERT Legacy components on City right of way or in their possession.

2.0 PROJECT OVERVIEW

2.1 PROJECT DESCRIPTION

2.1.1 Introduction

Two major freeways (I-94 and I-35E) come together in a common section in the vicinity of downtown St. Paul. This common section and the nearby freeway approaches have historically had high accident rates. The Minnesota Department of Transportation Office of Advanced Transportation Systems and the City of St. Paul jointly developed and deployed an incident management project under the acronym DIVERT (During Incidents Vehicles Exit to Reduce Time). DIVERT was conceived to manage the effects of incidents on I-94 and I-35E. Prior to DIVERT freeway incidents would cause large queues and substantial vehicle delay. Also, any diversions that motorists attempted through the downtown St. Paul surface street network were unplanned, disorganized and inefficient. The goal of DIVERT was to provide management strategies during periods of freeway incidents by routing diverted traffic over City surface arterials in a planned, coordinated manner. The resulting service along the managed diversion routes would be expected to be higher than the service available by remaining on the freeway.

2.1.2 System Concept

One of the major initiatives of the DIVERT project was to improve the joint management of freeway and city traffic through enhanced institutional cooperation between Mn/DOT and the City of St. Paul. This enhanced cooperation would allow the DIVERT objectives to be achieved through a three phased process of incident detection, route guidance and traffic signal control. In so doing, DIVERT linked together two significant systems which formerly had no linkages or interactions. The first of these systems is the Freeway Management System operated by the Minnesota Department of Transportation (Mn/DOT) from their Metropolitan-wide Traffic Management Center (TMC). This system features an extensive set of roadway detectors and surveillance cameras along the freeway network. The detector data and surveillance camera views are returned to the Mn/DOT TMC located in downtown Minneapolis. The second major system is the City of St. Paul downtown traffic control system. The City operates a 120 intersection, UTCS-type central based control system for its downtown network. This system is operated from the St. Paul Traffic Control Center (TCC). The St. Paul TCC and the Mn/DOT TMC facility are separated by a distance of ten miles.

Prior to DIVERT, the detector and surveillance data captured at the Mn/DOT TMC was not transmitted to or directly shared with the City of St. Paul. The DIVERT system architecture was developed to facilitate the sharing of these data between the Mn/DOT TMC and the City TCC. The final design of the system placed the DIVERT system control components at the City of St. Paul TCC. During incident occurrences the City staff play a key role in actively diverting freeway network traffic off of the mainline and through their municipality using a pre-planned, managed system. This is the first example in Minnesota where city staff actively manage the Mn/DOT freeway network through their municipality.

2.1.3 System Components

2.1.3.1 Incident Detection

The architecture of the DIVERT system was designed to accomplish expert system or "hands off" incident detection and management. For the operational test, as a new system, DIVERT was to be run with a process of detect/verify/control, with operator confirmation involved prior to the initiation of diversion management strategies. The initial incident detection was planned to be accomplished directly by the DIVERT system central processor. The DIVERT system was designed with continuous access to freeway detector information from the Mn/DOT TMC. The real time detector data were smoothed and an algorithm was used to enable the system to recognize the potential need for a diversion routing. Secondary incident detection would occur through the freeway based camera surveillance system. The TMC operators who visually observe incident conditions along the St. Paul portion of the metropolitan freeway system could notify the City of St. Paul operators to the potential incident conditions. In a similar fashion, the City of St. Paul operators were to have access to the Mn/DOT freeway camera system so they could also visually detect incident congestion conditions through the shared camera feed to the St. Paul Traffic Control Center.

2.1.3.2 Route Guidance

Within the corridor, there are two basic diversion routes which can be utilized to carry significant diversion volumes during full or partial blockages of the freeway system. Both diversion routes are supported by a network of exit/entrance ramps providing access to and from the freeway system. One of the routes is Kellogg Boulevard, a major signalized arterial which provides diversion routing possibilities in both directions to bypass the freeway commons section. There are 16 signalized intersections along this 2.5-mile long diversion route. The second route is the one-way pair of 11th and 12th Streets, which also provide the opportunity for significant additional capacity bypassing the freeway common section. There are 13 signalized intersections along this one-way pair.

Three types of signs were used in the DIVERT system to guide motorists to and along the diversion routes. Freeway changeable message signs (CMS) were used to inform freeway motorists of an incident. CMSs were installed on the four freeway approaches to the common section. Initially, these CMSs were portable and communication was by cellular telephone. (Future Mn/DOT freeway initiatives will provide permanent CMS signing in the area.) Additional static trailblazer route marker assemblies were installed to help guide motorists along the arterial diversion routes. A third type of sign was required to eliminate conflicts between the existing static trailblazer route markers along portions of the arterial diversion routes. These signs were needed for locations where during an incident diversion scenario the motorist's route back to the freeway was different than during normal times. A sign was developed for DIVERT that is only visible during incident diversion. This sign is a light-emitting-diode (LED) "blank-out" type that is turned on or off, or the direction of the arrow is changed, by the DIVERT system operator, as appropriate.

2.1.3.3 Traffic Signal Control

A basic premise of the DIVERT strategy is that the service level provided to the diverted traffic along the arterials is better than the service level on the congested freeway during periods of incidents. To support this premise, the DIVERT system was designed to constantly monitor an extensive set of detector loops placed on the three arterial diversion routes. When an incident occurs on the freeway and potential diversion conditions exist, the DIVERT system conducts two actions. First, based on the current volumes along the surface arterials, the system assesses the ability of the arterial system to accommodate additional, diverted traffic. Second, if available capacity does exist on the diversion routes, the system recommends a predetermined diversion timing plan from its library of 17 special diversion management timing plans. The 17 special timing plans were developed to cover the

multiple combinations of traffic conditions for different times of the day, different background volume levels and different routings of the diverted traffic. The actual timing plan implementation is currently initiated by operator intervention with the system.

As the DIVERT system runs in the background to the main City central system, the 17 special timing plans reside within the DIVERT processor. When the operator initiates the timing plan change, the DIVERT system downloads an override command to the local intersection and then also downloads the selected plan. The selected plan is locally stored and executed at each of the divert arterial intersections during the declared incident management period. At the end of the incident management period the operator issues a "return" command which allows each of the DIVERT arterial intersections to transition back into normal central system control.

2.1.4 System Operation

The DIVERT system was designed to be operated with very little staff. The system architecture and control was developed to ultimately be used in a hands-off manner. During the operational test, the diversion management strategies could only be initiated through operator confirmation and direct selection of control strategies. Because the City of St. Paul TCC is not constantly staffed, the system was designed with a paging capability. The design specified that when the DIVERT system recognized potential freeway diversion conditions based on thresholds established by the project team, the system would page the on-duty St. Paul operator. The operator could then return to the TCC to monitor incident conditions and, if necessary, initiate the incident management strategies.

The diversion routines were only meant to be initiated for major incidents that cause substantial congestion along the freeways. The threshold determinants include occupancy, change in speed and change in volume. In the early stages of the project, the threshold values were calibrated and adjusted to reach levels which properly notified the system operator of potential diversion needs, with a minimum number of false calls. The informal operations plan specified that upon receiving a notification and confirming the need for diversion, the operator may initiate the diversion routine. Each response strategy, or plan, is a combined action that includes specific guidance sign messages and associated signal timing plan changes to facilitate the flow of diverted traffic to the surface arterials.

2.1.5 Project Partners/Team

- Ben Osemenam, Mn/DOT Office of Advanced Transportation Systems - Project Manager
- John Bieniek, Mn/DOT Traffic Management Center - Project Team Member
- Steve Misgen, Mn/DOT Office of Traffic Engineering - Project Team Member
- James McCarthy, FHWA - Project Team Member
- Paul Kurtz, City of St. Paul - Project Team Member
- Bob Hamilton, City of St. Paul, Project Team Member
- John Maczko, City of St. Paul, Project Team Member
- Allan Klugman, Westwood Professional Services, Inc. - Independent Evaluator
- Ali Gord, Booz-Allen & Hamilton, Inc. - Project Team Member
- Bob Sands, Edwards and Kelcey, Inc. - Project Team Member
- Arnold Rubenstein, Edwards and Kelcey, Inc. - Project Team Member
- Jeff Hilden, Edwards and Kelcey, Inc. - Project Team Member

Others

- Ping Yi, Mn/DOT Office of Advanced Transportation Systems - Project Manager, September 1993 through August 1994
- Samuel Boyd, Mn/DOT Office of Advanced Transportation Systems - Project Manager, August 1994 through December 1996
- Gary Rylander, Edwards and Kelcey, Inc. - Project Team Member, September 1993 through January, 1996
- Mike Belrose, Westwood Professional Services, Inc. - Evaluation Support

2.1.6 References

Appendix C contains a listing of all major DIVERT references. The best detailed, technical description of the project is contained in “Summary Report Detailed System Design – St. Paul Incident Management (DIVERT) Operational Test,” Edwards and Kelcey, Inc., November 1997.

2.2 EVALUATION DESCRIPTION

2.2.1 Evaluation Overview

This document serves as the independent evaluation of the DIVERT ITS operational test. The planning for and execution of the evaluation was conducted by Westwood Professional Services using FHWA-provided guidelines on the operational test evaluation process. Westwood was assisted by Booz Allen & Hamilton, Inc., the FHWA's evaluation coordination consultant to the Federal ITS Operational Test Program.

2.2.2 Evaluation References

The two major evaluation references are the evaluation plan document ("SPIM Operational Test Evaluation Plan," Westwood Professional Services, Inc., January 1995) and the detailed evaluation plan ("DIVERT Detailed Evaluation Plan," Westwood Professional Services, Inc., January 1996). These reports are cited in Appendix C.

2.2.3 Project Goals and Objectives

The evaluation planning was guided by the major goals and objectives of the project. These Goals and Objectives are summarized below:

PROJECT GOALS AND OBJECTIVES

Goal	Objective
1. Manage traffic flow in the I-94, I-35E and St. Paul Central Business District (CBD) areas when incidents occur in the I-94 / I-35E "common section" of the freeway system.	• Minimize freeway congestion and secondary incidents due to initial incidents in the I-94 / I-35E common section. • Minimize traffic disruption and congestion in the St. Paul CBD during incidents in the I-94 / I-35E common section. • Divert traffic from the freeway during incidents. • Effectively inform motorists of, and guide motorists along, designation arterial bypass routes. This includes providing information on where to exit the freeway, what city streets to use, and where to re-enter the freeway. • Expedite travel time for motorists using the designated bypass routes.

PROJECT GOALS AND OBJECTIVES, cont'd.

2. Improve institutional interaction and agency coordination for incident response.	• Provide improved surveillance information (data and video) to support selection and operation of appropriate diversion strategies. • Provide a faster response to incidents in the freeway corridor. • Permit real-time control of route guidance and signing information along the freeway and designated arterial diversion (bypass) routes. • Provide real-time control of the traffic signals along the arterial diversion routes in response to diversion traffic demands. • Share incident occurrence and management information between Mn/DOT and the City of St. Paul. • Coordinate traffic control / management strategies in the corridor between Mn/DOT and the City of St. Paul. • Identify incident management strategies suitable for DIVERT system expansion. • Identify incident management strategies suitable for application to other corridors.
3. Apply new techniques in the development and implementation of DIVERT.	• Evaluate the operation of the traffic management and traveler information hardware and software, as well as supporting technology, to provide incident detection, management and control. • Assess the use of real-time controlled special signing for guiding motorists to and along the arterial diversion routes. • Assess the effectiveness of twisted-wire copper pairs (TWP) for transmitting full-motion video images to support the incident management and control system.

2.2.4 Evaluation Goals and Objectives

Based on the project goals and objectives summarized above, the evaluation team established a set of primary Evaluation Goals and secondary Evaluation Goals to guide the conduct of the evaluation. The evaluation goals are summarized below:

Primary Goals	Secondary Goals
1. Evaluate System Performance	1.1 Assess general performance of the system as a whole 1.2 Assess system architecture 1.3 Assess performance of the surveillance system 1.4 Assess performance of the communication system 1.5 Assess control component
2. Evaluate System Benefits	---
3. Evaluate System Costs	---
4. Evaluate User Satisfaction	---
5. Evaluate the Effect of Other System Impacts	---
6. Evaluate Institutional & Legal Issues	---

2.2.5 Evaluation Reporting

Section 3, the next section of this report, summarizes the major evaluation assessments based on the primary and secondary evaluation goals delineated above.

3.0 COMPONENT ASSESSMENTS

3.1 SYSTEM ARCHITECTURE ASSESSMENT

3.1.1 Overview

The DIVERT concept includes total incident management with incident detection, motorist information (along the freeways and city arterials) and traffic signal control. Furthermore, the DIVERT concept envisioned this incident management to take place in a multi-agency (Mn/DOT and City of St. Paul) and multi-location (TMC, City Hall Annex, City Public Works Shops) environment. A goal of the project was to design the system architecture to support this multi-agency, multi-location approach.

The main purpose of this test plan is to assess how the system architecture supported this major project goal of multi-agency, multi-location management. This plan also examines system and component reliability. As all components are linked together, they need to properly function to provide the service and functions contained in the original DIVERT system concept. The table at the end of this section summarizes the failure log for all system components. The failures relating to system architecture design and performance are discussed within this section.

3.1.2 Evaluation Method

The assessment of the system architecture is primarily based on the subjective comments provided by the systems operators and administrators. These operator comments were supplemented by maintenance logs and the evaluator's observations during the course of the operational test.

3.1.3 Findings

The system architecture was designed and implemented based on the project concept as originally developed in 1994-1995. That concept detailed a high degree of automated operation, or at least the potential for automated operation. Many of the system architecture decisions were based on efforts to achieve this actual or potential automation. In addition to the decisions based on desired automation, other decisions were generated by the multi-agency multi-location structure of this project.

3.1.3.1 TMC-DIVERT Link

One of the key manifestations of the multi-agency/multi-location design is that TMC derived detector data needed to be analyzed at the DIVERT computer in St. Paul. The general path for this is as follows: A personal computer was placed in the TMC by the DIVERT project. The role of this computer was to "capture" TMC detector data (for the detectors of interest to DIVERT) and prepare that data for transmission to the main DIVERT system. The detector data was then transmitted to the main DIVERT computer which processed the data through its algorithms to perform the incident/congestion detection analysis.

Over the course of the 18 month operational test the DIVERT operator recorded 27 times when this link was lost. During these times the automatic incident detection feature was totally lost. For the vast majority of these "lost communications link" events, the situation was fixed by having TMC personnel reboot the DIVERT data capture computer that was located at the TMC. This action reset the communications parameters and reestablished the link.

3.1.3.2 City Annex-City Shop Link

Another example of the multi-location issue deals with the desire to link the City Hall Annex and City Shops. It was apparent in the original project planning the majority of the City's interaction with the DIVERT system would occur from the City Hall Annex facility in Downtown where the DIVERT operator is located. However, the City requested that full functionality also be provided at the Public Works Shop on Dale Street. The original system design and implementation carried out this request. During the course of the project, there were intermittent problems in maintaining communication to the shop.

3.1.3.3 Communications to Portable Changeable Message Signs

The freeway signing feature was achieved through portable changeable message signs controlled by cellular phone communications. The sign manufacturer supplied the support programs and protocols for these portable signs. The DIVERT system supplied the communications hardware (computer port and modem control) to manage the signs. In addition, the DIVERT system was designed with a "shell" to access the sign manufacturer's protocols. The portable sign approach was chosen for three reasons:

- DIVERT was designed as a test project and budget resources needed to be wisely allocated. The diversion message service could be accomplished and tested on portable signs at much lower cost than the permanent sign option.
- For the operational test the DIVERT freeway signing was to be an effort separate from the TMC freeway signing program. Therefore, DIVERT needed its own self contained system with messages controlled by the St. Paul DIVERT operators. The portable signs represented an efficient way to accomplish this.
- During the design phase of the project it was envisioned that for all (or most) of the DIVERT freeway sign locations new overhead variable message signs would be coming on-line as part of other TMC efforts. In the future, if DIVERT were to move forward as a permanent deployment, the DIVERT messaging could be ported to those expected future signs.

Over the 18 months of the operational test the DIVERT operator recorded 48 instances where communication was lost to a portable sign. On 15 of these occasions the sign was "hung" with no ability to reset itself automatically. When this occurred there was no way to download a message to the sign until a person was dispatched to the field to manually reboot the sign. The following factors contributed to the portable sign communications problems.

- One of the four signs (northbound I-35E) was determined to be placed in an area of very weak cellular phone coverage. This problem was addressed by installing a stronger, directional, Yaggi antennae on this sign. According to the sign supplier, only approximately 1 in 120 signs that they supply require this type of antennae to function, so this clearly was an unusual zone of poor cellular coverage.
- With the original organization of this project, the sign vendor was not a project partner involved in the design of the overall system; the sign vendor was a supplier who responded to a sign specification. This specification was written before the DIVERT system was complete. The control protocols supplied by the sign vendor met the requirements of the sign specification, however, there were compatibility problems between the sign vendor control protocols and the integration of those protocols into the DIVERT system environment. The sign supplier and system designer spent a significant amount of time analyzing the system compatibility issues. The project manager, Ben Osemenam, as part of his effort in role definition of all project participants, asked both parties to submit a written definition of their roles. With that information, he was able to negotiate a fix, whereby the sign supplier changed out the modem in each of the four signs to provide a "simpler" modem, but one that integrated better with the DIVERT system

software. The analysis of the problem and the equipment and labor for the modem change outs were provided by the sign vendor at no additional cost to the DIVERT project.

3.1.3.4 DIVERT-MTCS Interaction

An INTEL 386 computer serves as the heart of the DIVERT system. A Concurrent model 3205 computer system operates the Saint Paul MTCS traffic signal control computer system. The 386 system is installed in the Concurrent chassis but is operated as a totally separate system. The 386 system is operated from an external work station; it is externally connected to, and works with, the Concurrent system. Section 3.5.2 of the DIVERT Summary Report and Detailed System Design Document provides a thorough discussion of the DIVERT central processor.

Under normal operation, the MTCS traffic control software operating on the Concurrent computer system manages and operates all of the traffic controllers in the DIVERT area over a city owned twisted wire communication network. The MTCS system operates on a once per second communication basis using holds and force-offs to control traffic signal controllers connected to the system. The proprietary MTCS software did not readily allow software modifications to incorporate changes to support timing from the DIVERT system. Accordingly, in order to provide special DIVERT traffic signal timing, the system designer developed a means external of the traffic control software to provide DIVERT system timing.

Special DIVERT system software and a custom, relay based, interface were developed to oversee the operation of the Concurrent traffic control system software and to provide DIVERT timing. The relay interface is installed between the Concurrent computer system and field equipment. During times when it is necessary to provide DIVERT timing, the DIVERT system computer and the special interface selectively collect information sent from the Concurrent system and return information to the Concurrent system to allow the Concurrent system to operate as if no intervening components existed. At the same time the DIVERT system communicates directly with the affected traffic signal controllers and sends the appropriate DIVERT timing to the field equipment. This approach allows normal Concurrent system operation to continue and enables the DIVERT system to modify the scheduled operation to provide specifically appropriate DIVERT network timing. In addition, the design also allows effective user interaction during periods when the Concurrent system is off-line.

The integration of the DIVERT system components with the inplace MTCS system operates very well and provides the service requirements outlines in the concept developed for the project. This element, in addition to providing the proper system interaction, has also proven to be a highly stable and reliable hardware/software implementation.

DIVERT OPERATIONAL TEST
SUMMARY OF SYSTEM COMPONENT FAILURE LOG
December 9, 1996 - June 30, 1998

FAILURE TYPE	SOLUTION	# OF OCCURRENCES
Communication Lost to VMS		
Communication Lost to VMS No. 1	ADDCO Repaired/Rebooted	5
	E & K Repaired/Rebooted	1
	City Repaired/Rebooted	3
	U.S. West Repaired/Rebooted	1
	TMC Repaired/Rebooted	1
	Subtotal - Communication Lost to VMS No. 1	11
Communication Lost to VMS No. 2	ADDCO Repaired/Rebooted	3
	E & K Repaired/Rebooted	2
	City Repaired/Rebooted	3
	U.S. West Repaired/Rebooted	1
	TMC Repaired/Rebooted	0
	Subtotal - Communication Lost to VMS No. 2	9
Communication Lost to VMS No. 3 (Before Antennae Replaced)	ADDCO Repaired/Rebooted	5
	E & K Repaired/Rebooted	1
	City Repaired/Rebooted	0
	U.S. West Repaired/Rebooted	0
	TMC Repaired/Rebooted	0
	Subtotal - Communication Lost to VMS No. 3 (Before Antennae Replaced)	6
Communication Lost to VMS No. 3 (After Antennae Replaced)	ADDCO Repaired/Rebooted	5
	E & K Repaired/Rebooted	2
	City Repaired/Rebooted	3
	U.S. West Repaired/Rebooted	1
	TMC Repaired/Rebooted	1
	Subtotal - Communication Lost to VMS No. 3 (After Antennae Replaced)	12
Communication lost to VMS No. 4	ADDCO Repaired/Rebooted	7
	E & K Repaired/Rebooted	1
	City Repaired/Rebooted	1
	U.S. West Repaired/Rebooted	1
	TMC Repaired/Rebooted	0
	Subtotal - Communication Lost to VMS No. 4	10
	Total - Communication Lost to VMS's	48

DIVERT OPERATIONAL TEST
SUMMARY OF SYSTEM COMPONENT FAILURE LOG, cont'd.
December 9, 1996 - June 30, 1998

FAILURE TYPE	SOLUTION	# OF OCCURRENCES
Detector Communication Lost from TMC	TMC Repaired/Rebooted	25
	City Repaired/Rebooted	1
	E & K Repaired/Rebooted	1
	Total - Communication Lost from TMC	27
Video Feed Lost from TMC		On-going & then permanent
DIVERT Central System Hardware		
Server Down	City Repaired/Rebooted	3
Work Station Crash	City Repaired	1
Work Station Wrong Time	City Repaired	1
	Total	5
DIVERT Central System Software		
Event Log Down	E & K Debug	2
No Current Record Reported	E & K Debug	1
VMS Icon Bug	E & K Debug	1
Date and Time Wrong	E & K Debug	1
No Communication to VMS 2	E & K Debug	1
Could Not Start Scenario	E & K Debug	1
TMC Communication Protocol Out	City Reset	1
	Total	8
VMS Display Problems		
Flicker on VMS	ADDCO Repaired	1
VMS Display Error	City Reboot	2
VMS Display Error	E & K Restored Data Base	1
VMS Modem Out	City Replaced	1
VMS Blinking	City Rebooted	1
	Total	6
Arterial Blankout Signs		
Sign Flashing	No Action Taken	1
	Total	1
CCTV Picture Problems		
Scrambled Picture	City Tuned	2
Poor Picture Noted	No Action Taken	9
Poor Picture	City Repaired	2
No Picture	City Repaired	1
CCTV Iris Problem	City Repaired	1
	Total	15

DIVERT OPERATIONAL TEST
SUMMARY OF SYSTEM COMPONENT FAILURE LOG, cont'd.
December 9, 1996 - June 30, 1998

FAILURE TYPE	SOLUTION		# OF OCCURRENCES
CCTV Control Problems			
Pan, Tilt, Zoom Major Problems	City Repaired		2
Pan, Tilt, Zoom Low Performance	PTZ Controller Replaced		Ongoing
		Total	2
Equipment Damaged/Impacted in Field			
Signal Controller Hit by Vehicle	Replaced by City		1
VMS Hit by Vehicle (Snowplow ?) and Turned	Moved Back by Mn/DOT		1
		Total	2

EQUIPMENT REPAIRS/REPLACEMENTS	RESPONSIBLE PARTY
New Antennae for VMS 3	ADDCO
Change out Modem in All 4 Portable Message Signs	ADDCO
Repair of VMS Dial Up Line	U.S. West
Change out of PTZ Controllers for All 6 Cameras	City
MTCS Line Out, Relay Replaced	City

3.2 SURVEILLANCE SYSTEM ASSESSMENT

3.2.1 Overview

The DIVERT system concept relies on various means of field data collection for input to the detection algorithms, and operator decisions to initiate a full system diversion. For the purposes of this evaluation these various means are grouped as the surveillance components of the system. These components include:

- loop detectors located along the freeway; these were planned as input to the incident detection algorithms
- loop detectors along City streets; these were planned as input to the diversion plan selection decision
- CCTV on the freeway links; these were planned to be used in the DIVERT project primarily to allow the City operators to view the actual freeway status in real time; since the structure of DIVERT calls for close coordination and cooperative decision making between the City and TMC operators, one of the benefits of providing these freeway camera views is that the St. Paul operator would see the exact same view as the TMC operator
- CCTV on the arterial links; as part of the project six new CCTV cameras were installed on project arterial bypass routs; these allow the City operators to visually observe operations along a bypass route before initiating a diversion, then during the diversion the operators can observe the results of the diversion plan they selected and they can change or fine tune the plan, if needed. .

3.2.2 Evaluation Method

The assessment of the surveillance system is primarily based on the subjective comments provided by the systems operators. These operator comments were supplemented by the evaluator's observations during the course of the operational test.

3.2.3 Findings

There were a number of reliability problems associated with the components of the surveillance system. (These are also discussed in the System Architecture Assessment.) The findings below primarily apply to the situation when the components are properly working.

3.2.3.1 Freeway Loop Detectors

The DIVERT system was able to effectively capture, process, use and record the TMC loop detector data when the system and its communication linkage were properly working. However, frequent communications failures between the TMC and the City Hall Annex rendered this element unstable.

The theoretical design for DIVERT makes extensive use of freeway detector data to assess the need for diversion service. Even when all of the technical elements of the detection system were properly working, the detector data from the TMC was insufficient for ideal incident detection on one of the four freeway approaches. This occurred because the amount of detectors in that direction is fairly low and no new freeway detectors were added as part of this project. The system designer developed the incident detection algorithm to work as well as it could with the available number (and spacing) of loop detectors.

3.2.3.2 City Street Loop Detectors

In the original design of DIVERT the City street loops were intended to support the automated DIVERT decision matrix by allowing the system to consider traffic conditions on the City streets as the system analyzed the need for diversion from the freeway and the opportunity to provide diversion service on the City streets. Towards this end, the City of St. Paul as part of their agency partnership contribution, installed about 40 new loop detectors along City diversion routes and main cross streets along the diversion routes. In reality, the way the decision matrix for potential diversions was carried out (with its main emphasis on operator involvement and manual intervention) the role of the City detectors was greatly diminished. By the end of the project only about half of the 40 new loops were properly working and reporting data back to the DIVERT system. Localized communications issues in the field and construction activities that damaged loops were the reasons for the poor loop performance. Since, their value in the DIVERT decision matrix was diminished, there was no impetus to repair the damaged loops.

3.2.3.3 Freeway CCTV

The TMC maintains three cameras near the Capitol Area Interchange. These three cameras provide very good coverage for the four directions of the DIVERT system. However, for several months during the operational test, the City was not able to receive a feed showing the views from these three cameras. Prior to the beginning of DIVERT the City of St. Paul (and several other agencies) received equipment and communications linkages from the TMC to allow those agencies to view (but not control) TMC cameras of interest to that agency. This effort was not related to DIVERT; it was part of a separate outreach effort by the TMC. During the design phase of DIVERT the TMC camera views at the City of St. Paul Annex were working well. Thus, DIVERT was designed with the assumption that this management tool would be available for the St. Paul operators.

Early in the DIVERT operational test period the TMC camera views became unavailable. Two factors caused this. First, the TMC changed switching equipment in its facility and, in so doing, lost the ability (at least temporarily) to connect to the City of St. Paul. Second, the TMC experienced problems with its communications linkage to the City. The TMC tried to identify the cause of the video communication failure to St. Paul. However, with limited resources available to support the links to other agencies, the TMC was unable to complete the problem identification before the data collection period for this evaluation was completed. Therefore, for the majority of the operational test period the City did not have access to the TMC camera views of the freeway. It should be noted however, that with the City CCTV cameras located on 11th and 12th Avenues the City did have some ability to view part of the DIVERT freeway network and those cameras functioned during the operational test.

3.2.3.4 City CCTV

As part of DIVERT, a total of six CCTV cameras were installed along the three diversion routes. Prior to this project the City did not have any CCTV cameras. During the first half of the operational test period the City experienced maintenance issues with the Pan/Tilt/Zoom (PTZ) mechanisms on several of the cameras and even when working, the PTZ control was very slow. Eventually, the PTZ controllers were replaced, under warranty, by the camera supplier and the performance of the cameras was greatly enhanced.

The City staff made excellent use of the camera facilities to visually monitor diversion routes during the three declared incidents and during times when diversion was considered but not implemented. In addition, the City made extensive use of the cameras to monitor special event traffic in downtown and to check and monitor traffic signal performance during typical weekday periods.

3.3 COMMUNICATION SYSTEM ASSESSMENT

3.3.1 Overview

The performance of the communication system was vital to the overall performance of the DIVERT system. With the multi-agency and multi-location approach, there was a strong need for effective and reliable communications facilities. Two main communications networks are employed in this system to support the multi-agency and multi-location design. One of these networks is from the TMC to the City Hall Annex; the second one is from the City Hall Annex to the City Shops on Dale Street.

3.3.2 Evaluation Method

The assessments of the communications systems are primarily based on the subjective comments provided by the systems operators. These operator comments were supplemented by the evaluator's observations during the course of the operational test.

3.3.3 Findings

3.3.3.1 TMC to City Hall Annex

Communications from the TMC to the City Hall Annex, when working, provided effective data that met the requirements for DIVERT system operation. During the course of the test there were several periods when communication from the TMC was lost. These events required software fixes by the DIVERT system developer. While communications were out, DIVERT did not function as originally designed. The project team realized that when electronic communications were lost from the TMC, the automatic incident detection feature of DIVERT was lost, but the incident management functions were not impacted. Therefore, to be able to implement DIVERT, the team established an alternative incident detection technique utilizing the traditional means of TMC incident detection (camera surveillance, driver notification) combined with TMC operator calls to the City of St. Paul.

3.3.3.2 City Hall Annex to the City Shops on Dale Street

During the course of the project, the communications link to the Dale Street Shop was out intermittently. The original DIVERT concept called for the Dale Street Shop to have full DIVERT management and control capabilities. This would provide a back-up, or second location of operation for the City. As the project proceeded, an operational decision was made to only allow DIVERT system intervention from the Annex site by the two official DIVERT operators. Shop personnel were to retain the ability to view City CCTV camera feeds, but not control them via the pan/tilt/zoom features. Also, the shop personnel would not interact to load DIVERT signal timing. With this reduced role for the shop personnel, the intermittent outages to the shop were not a serious impact.

3.3.3.3 Twister Copper Interconnect

The City's inplace signal system interconnect was used to transmit live video from the six arterial-based CCTV cameras to the City Hall Annex. This system was reliable, technically effective and cost efficient. This was a successful demonstration of the use of copper cable to transmit video.

3.4 CONTROL COMPONENT ASSESSMENT

3.4.1 Overview

For the purposes of this evaluation the assessment of the control component was divided into two main portions:

- the ability of the system to accurately detect incident conditions, and
- the ability of the system to manage incident conditions when a formal DIVERT incident is declared

3.4.2 Evaluation Method

The assessment of the control component is primarily based on the subjective comments provided by the systems operators. These operator comments were supplemented by the evaluator's observations during the course of the operational test.

3.4.3 Findings

3.4.3.1 Incident Detection

A significant portion of the project resources were expended on trying to develop a suitable incident detection algorithm. Early in the concept development portion of this project a decision was made to design the DIVERT system to have fully automated capabilities (although the fully automated operation was not to be implemented within this operational test). In order to have the potential for automated operation the system needs a robust incident detection algorithm characterized by three attributes:

- a high percentage of correct incident identifications
- a low number of false incident alarms, and
- a short time to detect incident conditions

Although the system was not implemented in an automated *control* mode, the incident detection algorithm was used to automatically alert the operator of a "potential incident condition". This alert went out over the pager network, whereupon the operator could then use all of the resources of DIVERT to decide if an actual formal diversion would be initiated. Therefore, the incident detection element that was evaluated within this test was:

- the ability of the system to detect the appropriate times for the operator to be alerted, with the understanding that these alerts were for the purpose of further assessing "potential incident" conditions

This implies that on many occasions the operator would be paged knowing that there is a high probability that no diversion action would be taken.

Over several months in the first half of the operation test period the system designer refined and recalibrated the incident detection algorithm to eliminate a high number of false alarms (i.e., false alarms relative to the objective of detecting potential incident conditions). In calibrating the algorithm the system designer faced two challenges:

- The freeway area covered by DIVERT contains fewer detectors than desired for robust algorithm performance. (One of the freeway directions was particularly lacking in detectors.) The

algorithms were set up to work with the detectors inplace on I-94 and I-35E; no new freeway detectors were added under DIVERT. This lack of sufficient detection hampered the ability to completely and accurately detect incident conditions throughout the DIVERT service area.

- At the beginning of the project there was not an agreed-upon definition of an incident for DIVERT implementation. The TMC has a definition of an incident, which they use system wide throughout the metropolitan area. However, this TMC definition differed from the description advocated by the City of St. Paul. The TMC, in keeping with their metro-wide definition of an incident, favored DIVERT implementation at lower freeway congestion levels than did the City. The City's view was that DIVERT would only be turned on for the most restrictive conditions on the freeway, where DIVERT would clearly provide a faster travel time than that available by staying on the freeway. In the spring of 1997 DIVERT underwent a project management change and began a significant effort toward resolving outstanding project issues. Relative to incident detection, two major objectives were reached. First, the project management team reach formal agreement on the level of congestion required for DIVERT implementation. (This level was essentially the level recommended by the City of St. Paul.) Second, the system designer, using the defined incident description level, calibrated the detector thresholds necessary to trigger an incident detection. Section 3.8.4 of the DIVERT Summary Report and Detailed System Design Document provides a thorough discussion of the incident detection parameters and the calibration effort applied to them.

Ultimately, the system designer did produce algorithms that the team accepted as appropriate for the agreed upon target level of congestion for notification of potential incidents. Within this entire discussion of incident detection, one key fact must be noted. The DIVERT incident detection algorithm and pager notification process only worked when the DIVERT system was receiving valid detector data from the TMC. On several occasions the link from the TMC to DIVERT was not in operation and therefore the automatic incident detection process was disabled. (This problem is discussed in more detail in the System Architecture Assessment.)

A second, informal means of "incident detection" evolved during the course of the project. That means involved TMC operator notification of the City when the TMC became aware of potential incident conditions in the DIVERT service area. Through its regular monitoring of the entire metro freeway area via CCTV and state patrol dispatch information, the TMC quickly learns of any major incidents in the DIVERT service area. (This is especially true with the definition of a DIVERT incident that was ultimately agreed upon - i.e., a large incident with a significant amount of congestion.) When the TMC operators became aware of what they considered to be a potential DIVERT management incident the operators would directly notify the City operator through the pager network to initiate a phone conversation on the possible need to implement DIVERT service. When the detector link to the TMC was down this "human link" was the only source of DIVERT incident detection. Furthermore, even with the detector link up, this operator notification method appeared to be the most reasonable and suitable way of identifying and beginning action on potential diversion conditions.

3.4.3.2 Incident Management

The incident management and control portion of DIVERT is the heart of the system. This portion of the system includes the ability of DIVERT to:

- take command of and control the downtown St. Paul signals along the diversion routes
- turn on portable changeable message signs along the freeway, and
- turn on supplemental arterial guidance signs along the diversion routes

The following sections discuss the operations of each of these elements.

3.4.3.3 Signal Control

Section 3.5 of the DIVERT Summary Report and Detailed System Design Document describes the technical processes whereby the DIVERT system is able to override the City's MTCS Central Traffic Control System to download and run special diversion timing plans. This element of the DIVERT system worked very well. In all cases - during test periods and during the three managed incidents - the City was able to successfully download and implement the desired DIVERT timing plans to the appropriate system intersections. Furthermore, at the end of the incident management period the system successfully returned to normal MTCS control.

In addition to DIVERT incident operation, the City can make use of this element of the DIVERT system to download additional timing plans for downtown special event conditions. The DIVERT system extended the capability of the current central control system and thereby leveraged the previous investment in that system to provide additional service.

Based on the operator's comments, it is apparent that while the DIVERT system is complex, it is fairly easy to use for an experienced traffic signal system operator who has been thoroughly trained in the detailed use of DIVERT. Furthermore, the operator must be very conversant in the City's MTCS system to efficiently monitor the combined use of the two systems. Also, because of the system complexity, the operator needs periodic refreshing to stay conversant with the system. This is an important point in the DIVERT operations. During an incident management period the operator's task level is very high (e.g., watching monitors, talking to the TMC on the phone, downloading and verifying sign messages and signal timing data, and observing traffic progression on the arterials). The DIVERT operator must be able to quickly and accurately execute the needed DIVERT commands during this hectic period.

3.4.3.4 Freeway Changeable Message Signs

The DIVERT project included four portable, cellular driven, changeable message signs to inform freeway motorists of diversion instructions. Section 3.4.1 of the DIVERT Summary Report and Detailed System Design Document describes these signs. These signs informed motorists of the incident conditions and recommended diversion route. The portable signs were chosen for the operational test because the inplace overhead Mn/DOT signs either did not have capacity to add a DIVERT related message or were not well positioned to provide DIVERT messages. The original DIVERT concept envisioned that some or all of the portable signs would be replaced by future, permanent overhead signs; therefore the portable signs made sense for the limited time of the operational test.

The portable message signs were accessed and controlled by the DIVERT system. During the early months of the project there were significant difficulties in getting these signs to work reliably. Eventually the problems were resolved and the signs performed reliably. The issues surrounding this integration and communication problem are discussed in the System Architecture Assessment.

3.4.3.5 Arterial Guide Sign Control

The DIVERT project made use of eight "blank out" signs on the arterial diversion routes to provide supplemental guidance to diverted motorists. Section 3.4.2 of the DIVERT Summary Report and Detailed System Design Document describes these signs. These signs were activated through the special function capability of the on-street Type 170 signal controller. This special function was accessed through a command initiated by the DIVERT system. As with the signal timing control function, this special function performed well at all times, properly turning on and off the appropriate signs at the beginning and end of a managed incident event.

3.5 SYSTEM BENEFITS ESTIMATION

3.5.1 Overview

The DIVERT concept was developed to reduce freeway congestion during incident periods. The reduced congestion will provide the benefits of higher quality, safer traffic flow and will lead to corresponding reductions in fuel consumption and air pollutant generation. One of the original evaluation objectives was to quantify these system benefits.

3.5.2 Evaluation Method

Because of the unplanned, irregular occurrence of incidents, the evaluation plan proposed the use of traffic modeling programs to derive certain estimated systems benefits. The evaluation plan proposed the use of the CORSIM program for freeway modeling and the TRANSYT program for modeling surface street links. Accident data however, was to be collected from agency source records.

Although models were proposed to be used to estimate benefit values, the inputs to those models was to be based on actual detector counted values of traffic volumes at key locations during incident events. The "before" case for the modeling was to be represented by traffic flow with incident occurrences and no DIVERT system inplace. The "after" case was to be represented by the same incident occurrences, but with the full DIVERT system deployed. For the modeling, the proportion of diverted vehicles that follow the bypass route was to be determined by comparing detector volume reports at the off ramp and key check points along the route. Comparisons were to be made to typical base values for each station and to counts upstream of the stations during incidents.

The major evaluation objectives that were to be addressed through the modeling included:

- determination if DIVERT reduces congestion and improves traffic flow during incident conditions, understand how much diversion is necessary to improve conditions on the freeways
- determination if DIVERT reduces secondary accidents on the freeway during incident conditions
- determination if DIVERT reduces fuel consumption and air pollution generation

Under each of these evaluation objectives there were to be separate measures dealing specifically with the freeway links and the City street links (modeled data for congestion, fuel and air pollution; actual data for accidents).

3.5.3 Findings

During the course of the operational test period when it became apparent to the evaluation team that there would be very few managed incidents, the team dropped “reduction in secondary accidents” as an evaluation objective. It was clear that DIVERT would have an insignificant impact on this measure, and that no meaningful data could be collected on it.

During the one and one-half year evaluation data collection period, three incidents were declared and managed. Two of these were very short lasting 15 and 28 minutes respectively. The third managed incident lasted 2 hours and 16 minutes. Unfortunately, for all three of these incidents the background data collection modules were not properly working and no system data was available to the evaluator for running of the traffic models.

The DIVERT system, with its operational philosophy and hours of staffed operation, only managed one incident of any significant length of time. It is clear that the system benefit in terms of reduced congestion was quite minimal over the course of the operational test period.

3.6 SYSTEM COST COMPILATION

3.6.1 Overview

The development and operating costs for the DIVERT project were monitored by the Mn/DOT project management team and are summarized on the table on the following page. These costs can serve as a reference base for future similar projects.

DIVERT PROJECT BUDGET

	Mn/DOT Management & Installation	St. Paul Management & Installation	Edwards & Kelcey	Project Vendors	Westwood	Totals
Concept Definition & Preliminary Design	$15,000	$10,000	$85,000			$110,000
Detail Design & Deployment Engineering & Management (1)	$12,000	$15,000	$246,800			$273,800
Partnership Contribution (2)			$140,000			$140,000
Implementation						
CCTV		$69,000		$73,700		$142,700
Freeway Signs	$20,000			$99,600		$119,600
Arterial Signs		$5,000		$55,300		$60,300
Central System Hardware & Installation		$5,000		$46,700		$51,700
170 Controller Software Modifications				$9,250		$9,250
System Detectors		$26,000				$26,000
Operational Test Support	$10,000	$20,000				$30,000
Evaluation (3)	$10,000	$10,000			$131,000	$151,000
Totals	$67,000	$160,000	$471,800	$284,550	$131,000	$1,114,350

(1) Edwards and Kelcey fee includes PS&E, software and systems integration and training
(2) Edwards and Kelcey partnership contribution includes software and systems integration
(3) Evaluation fee includes $5,000 to subcontractor King's Engineering

3.7 USER SATISFACTION ASSESSMENT

3.7.1 Overview

Users of the DIVERT system can be divided into two broad categories: the motoring public and the system operators. It was felt that once implemented, the benefits of the DIVERT system would be apparent to both groups and the evaluation of the users' perceptions would be an important measure in assessing the project's success.

3.7.2 Evaluation Method

A test plan was structured to support this evaluation goal. For the motoring public portion, a "Motorist Survey" was developed by a professional market researcher. The plan was to administer that survey to drivers who the team thought would have a high exposure to the DIVERT system. The focus of the survey was on the drivers' awareness of DIVERT and assessment of it usability and benefit. The test plan called for recruiting drivers who frequently traveled the Capitol Interchange area. The surveys would be sent to these drivers. (Although not truly representative of a random sample, this method was selected by the evaluation team as an effective way to reach a suitable number of respondents, while making efficient use of the available evaluation budget.)

During the early stages of the evaluation work, initial steps were taken to recruit such drivers and the beginnings of a respondent pool were formed. However, during the extended shakedown period and early operational time period, it became apparent that the number of DIVERT managed incidents would be small. Therefore, it was quite likely that the recruited drivers would not even see a single DIVERT incident. Based on this determination, the evaluation team eliminated the motorist survey component.

Later in the operational test period, after the motorist survey component was dropped, the team attempted to identify another group of public respondents. This group focused on a different item - the impacts of diverted traffic on businesses and residents along or near the corridor. However, after this work item was identified there were no additional DIVERT incidents, and no further public survey work could be carried out.

For the system operators, a formal questionnaire was developed and administered to gather their opinions on the satisfaction with the system performance and operation.

3.7.3 Findings

3.7.3.1 Public

Because of the very limited number of managed incidents, the deletion of the motorist surveys and the suspension of the surveys to corridor businesses/residents, the evaluation was unable to determine valuable pieces of information - what did the public think of:

- the DIVERT service
- the means by which it was provided (e.g., sign size, location, message type, etc.)
- the impacts that nearby business managers and residents perceived to be caused by diverted traffic

3.7.3.2 System Operators

The level of satisfaction by the primary St. Paul operator was generally high, for the system elements and service when the system was properly operating. As described in the System Architecture

Assessment Section, DIVERT experienced a large share of technical difficulties and periods where one or more system elements were not available, thereby not allowing the full DIVERT concept to be available. In this evaluation those issues have been considered under the system reliability and availability category. Limiting the operator assessment to commentary on the system when it performed its stated functions, the St. Paul operator rated the system high on usability and functionality, with the caveat that to effectively operate the system, an operator did need to have a good knowledge of traffic control procedures. DIVERT was developed to manage traffic during periods of unusual traffic flow conditions. To accommodate these unusual demands the system requires a certain level of complexity in its operating options. Only an experienced traffic control operator could be expected to be able to effectively deal with this level of detail.

The TMC operators did not directly interact with the technical DIVERT system, hence, they generally had no comments or neutral comments about the technical aspects of DIVERT. (See the Institutional and Legal Assessment Section for a more thorough discussion of the TMC operator comments.)

3.8 ASSESSMENT OF THE EFFECT OF OTHER SYSTEM IMPACTS

3.8.1 Overview

Beyond its primary objectives, the DIVERT system is also expected to create benefits in other ways. For example, having DIVERT inplace and operational provides the City and Mn/DOT the opportunity to use some or all of the DIVERT system components to manage traffic during non-incident events (e.g., during construction or special events in the area). Conversely, DIVERT implementation may adversely affect other elements, such as disruption to non-diversion route City streets during special DIVERT timing plan implementation.

3.8.2 Evaluation Method

The assessment of the effect of other system impacts is primarily based on the subjective comments provided by the St. Paul system operator and administers. These comments were supplemented by the evaluator's observations during the course of the operational test.

3.8.3 Findings

The City of St. Paul made extensive use of DIVERT system elements apart from the times the system was used to actively manage (or check need for managing) an incident. The City made specific use of the following elements:

- CCTV Cameras: on many occasions the City made use of the six arterial based CCTV cameras to monitor traffic operations during normal peak periods and to recommend and check signal timing adjustments along the corridors. The cameras were considered by the City to be the best concurrent benefit of the DIVERT project.

- Special Signal Timing Plans and Download Capability: the City has added this capability to their set of tools available to better manage traffic during special event times (principally events at the Civic Center adjacent to the Kellogg Boulevard diversion corridor).

- Freeway Located Portable Message Signs: during April of 1997, when Mississippi River flooding caused street closures in downtown St. Paul, the City (with TMC's permission) entered a special sign message on the westbound I-94 portable sign to advise motorists of the street closure and recommended alternative route.

The DIVERT project generated another significant positive system impact, the building of communication channels between the TMC and City of St. Paul. Prior to this project the two operating agencies had very little interaction and virtually no shared operations experiences. DIVERT provided a forum for the two agency staffs to better understand each other's efforts to manage traffic in St. Paul. The new level of communications was employed for DIVERT and other traffic management situations. The establishment of these better levels of communication will certainly be utilized on other efforts in the future.

No adverse related effects, such as major side street delay, were observed or reported for the three managed incidents.

3.9 INSTITUTIONAL AND LEGAL ISSUES ASSESSMENT

3.9.1 Overview

The DIVERT project represented a dual-agency approach to traffic management. The project included both City and Mn/DOT participation in the development of operational plans, the funding and the operation of the system. Staffing for interactive agency involvement, management of activities, legal liability and administrative control are important issues to be considered in the evaluation of this project. The purpose of this section is to review these largely "non-technical" issues surrounding the project.

3.9.2 Evaluation Method

The assessment of the institutional and legal issues is primarily based on the subjective comments provided by the systems administrators and operators. These comments were supplemented by the evaluator's observations during the course of the operational test.

3.9.3 Findings

3.9.3.1 Agency Cooperation and Coordination

The team must have a shared vision: One of the most important points in the successful implementation of a multi-agency project is to create and maintain a shared vision of what the project goals are and how the technical aspects of the project should be carried out to meet those goals. The TMC, prior to DIVERT, had already established a definition of an incident. The TMC uses this definition system wide on the metropolitan area freeways. Meanwhile, the City of St. Paul developed a different definition of incident level and congestion for its description of when DIVERT service should be triggered. At the beginning of the project the discrepancy between TMC and City incident definitions was not addressed. After the operational test had proceeded for approximately six months, the project management team identified this as an issue that must be resolved. The team worked together to reach formal agreement on the level of congestion required for DIVERT implementation. After that the system designer was able to calibrate the detector thresholds to detect incidents at the level stipulated by the team.

The team should confirm the basis for the project: The idea for the DIVERT project was initiated in the early 1990's when the Capitol Interchange Area experienced a very high accident rate. As the DIVERT project concept was being developed, Mn/DOT in a separate effort completed geometric improvements to the area. These improvements corrected complex weave, merge and lane drop areas and afterwards the accident rate plummeted. Given the ultimately agreed upon definition of what level of incident would be managed, it is now clear that there will be very few of these incidents per year. This differs from the assumptions in place at the inception of the project planning.

The agencies should have open attitudes on operational control: One of the significant accomplishments of the project was an institutional agreement which allowed City operators to control messages on Mn/DOT freeways; this is the first time in Minnesota that this action had occurred. The design of DIVERT placed the device control with the City of St. Paul. This allowed the City operator to execute a single set of actions which controlled all aspects (freeway signs, arterial signs, signal timing plans). The TMC gave the City permission to turn on the freeway based DIVERT message signs. To preserve a proper level of TMC oversight in the process, the agreement included a commitment on the City's part to talk to the TMC operator before turning on the freeway signs.

The agencies and their designers must communicate their plans and needs: DIVERT was a development project that spanned across two distinct operating entities - the TMC and the City of St. Paul. Most of the development effort was geared toward devices and activities based at the City. However, there was also development of the linkage to the TMC for capture of detector data. In the midst of the DIVERT development process, the TMC changed its operating system platform. Although well justified for the overall TMC program, this caused significant difficulties for the DIVERT development team. A more timely notification and coordination of this change at the TMC would have aided the DIVERT development effort.

Since the inception of the DIVERT planning, the TMC has undertaken a separate effort to provide detector data to multiple agencies through a data distribution network. This system is currently under development and was clearly not available to the DIVERT project in a time frame needed by DIVERT.

The agency must understand the limitations of the shared resources: The TMC does not use its detector system for incident detection purposes (the TMC system primarily relies on the 911 calls for "incident detection"). Therefore, the number and spacing of the detectors are not necessarily placed in locations to facilitate incident detection. Also, the reliability requirements and maintenance attention are not based on the quality of data required for incident detection. The initial DIVERT concept called for the ability of the system to compute automatic incident detection on the freeways. To do this the DIVERT system captured and used the available TMC detector data; no new detectors were installed. However, since the TMC detectors were not originally installed for incident detection purposes, the DIVERT incident detection system was constrained to work with suboptimal detector placement and performance.

The designers must understand that "system architecture" includes the human interaction: The design phase of the project did not place a significant effort on understanding the operator to operator and operator to system interaction that would occur in a DIVERT management scenario. The interaction between TMC and City operators is complex and the technical tools provided by the system may have been different if this interaction was better understood.

Training of operators is a significant key to successful project implementation: The TMC has a large staff of operators who are based in the control room. Their jobs are quite complex and activity levels in the control room can be very hectic. It appears that DIVERT will only be invoked a few times a year. For a system with such a small number of activations, it is difficult to integrate those procedures into the TMC operators' work task process. Proper training is essential to their participation in DIVERT management activities.

3.9.3.2 Project Management

A developmental project needs a defined project management process by the sponsoring agency and major project developers/suppliers: From the beginning of the project on through the initial implementation, the project lacked a well defined and executed project management process. This lead to excessive project delays and made it difficult for the team to effectively solve project issues. After the system was operational for six months and a new Mn/DOT project manager was assigned, the team established and carried out a formal project management system. This featured clearly defined roles, responsibilities, deliverables and deadlines. With this management format in place the team was able to effectively address the remaining project technical issues and establish a stable, reliable system.

The project management team should strive to make accurate estimates of development timelines: System development and integration is a complex, time consuming process. At the initial stages of the project the timeline estimates were unrealistic and lead to frustration and dissatisfaction among

team members. This situation was corrected later on in the project. During the later stages of the operational test the team made accurate estimates of work efforts and timelines.

The system integrators role must be clearly defined and understood by all project participants: The DIVERT project attempted to make use of the system designer in a "limited system integration" role. This role was not understood by all team members and vendors and lead to confusion over participants' roles and responsibilities for many months of the operational test. Even in the creative, partnership team structures that are often developed for ITS test projects, there still must be clarity for major design, test and implementation accountability. Later in the test, when these roles and responsibilities were clearly delineated, the project team was able to address and solve the remaining project technical issues.

Develop operations and maintenance plans in advance of the test deployment: The operational issues surrounding DIVERT were significant and were not well understood by test partners prior to system turn on. Later in the project operations and maintenance plans were developed and followed. However, earlier attention to operations and maintenance planning in the design phase would have been beneficial to the agency partners.

The ongoing management of a development project is significant and important to the success of the project: DIVERT was under development, design and testing for approximately three years and then underwent an 18 month operational test. In this time Mn/DOT had three different project managers. Continuity of project management on a long term project is vital to its ongoing success.

The project management activities should include an extensive set of technical test activities to ensure system availability and reliability: DIVERT is a multi-element, linked project; failure of any aspect of DIVERT can render the system inoperable. The DIVERT test was hampered by a lack of adherence to formal acceptance criteria, system testing and documentation early on in the pre-operational phase. Eventually the team re-established the acceptance criteria and successfully applied those to ensure stable system operation.

The decision on the final "version" of the development effort must be clearly understood by all participants: Development projects can lead to a range of product/project completion levels (i.e., prototype, base system, commercially ready system). The needs of a test project may be met by a range of completion levels and the desired level must be understood and agreed upon by all partners. This agreement should occur at the earliest stages of the project. For DIVERT this was not well understood until late in the operational test.

3.9.3.3 Agency Resources

Agency budgets impact their ability to support new activities: The City of St. Paul traffic engineering division staffs the DIVERT system during normal working hours (approximately 8:00 a.m. to 4:30 p.m.). Outside of these hours the management tools of DIVERT can not be utilized. During the operational test, approximately three incidents that would have been good DIVERT management candidates were identified outside of these hours.

Agencies have difficulty maintaining elements that are not part of their core responsibilities: As part of an earlier, unrelated project, the TMC provided video feeds and switching capabilities to the City of St. Paul and several other agencies. DIVERT was designed with this resource assumed to stay in place. During the course of the operational test the video feed from the TMC was lost. The TMC trouble shooting effort to determine the cause of the lost feed was not completed by the end of the DIVERT evaluation data collection period. The loss of the TMC video link to the City impairs the St. Paul operator's ability to make a fully informed management decision.

3.9.3.4 Legal Issues

The need for coordination between agency partners is important in the early stages of the project: DIVERT featured an innovative public-public partnership between Mn/DOT and the City of St. Paul. The legal and contract requirements of the two public agencies differed substantially and took a significant amount of time to resolve. It is important to get the proper contracting authorities involved early in the process to get their support of the project and to ensure efficient execution of the necessary project agreements.

New software agreements should be written to be as open as possible: Like many projects that interact with inplace systems, DIVERT was affected by an inplace software agreement that limited access to the St. Paul central traffic control system software. In protecting their future interests, the public agencies should ensure that software agreements give the agencies the right to own or modify the newly produced software code.

4.0 DECISION TO ESTABLISH THE DIVERT LEGACY SYSTEM

4.1 OVERVIEW OF THE DECISION

The Mn/DOT Office of Advanced Transportation Systems (OATS) provides financial and management support for ITS operational tests, but not for ongoing deployment or long term operation. The OATS office fully supported the DIVERT project through its concept, design, preoperational and operational test phases. As the 18 month operational test period ended the project management team met at the project manager's request to decide what the ongoing status of the DIVERT system would be after the OATS involvement ended. The result of this meeting was that the team established a DIVERT Legacy System which will continue to operate with the full support of the Mn/DOT TMC and the City of St. Paul. The system will feature the stable, reliable elements of the DIVERT system that provide the major incident management goals of the original DIVERT concept. The DIVERT Legacy System represents the first time that a Mn/DOT Guidestar ITS operational test has made the formal transition to a permanent legacy system fully supported by the other agency partners.

The DIVERT Legacy System will feature:

- incident detection through traditional TMC methods
- diversion signing hosted on the TMC overhead variable message signs
- traffic signal control through the City's continued operation of the DIVERT central system
- a clearly defined operations plan, with a line of communications between the TMC and the City traffic control center
- clearly defined maintenance responsibilities

The following sections summarize the decision process employed to determine the legacy system and fully describe the features of the legacy system.

4.2 DECISION PROCESS AND OPTIONS

The decision on the future of DIVERT was made by team members from the Mn/DOT OATS Office, the Mn/DOT TMC, the City of St. Paul, and the Mn/DOT Traffic Engineering Office. When the decision was made the operational test data collection period was over and preparation of the final report was in process. Although the final evaluation report was not complete, the team believed that the major facts about the project were known and understood by all partners. Therefore, a knowledgeable decision could be made on the future of DIVERT.

The agency partners discussed three main options:

- Option 1: discontinue the system
- Option 2: continue the system with some/all control shifted to the Mn/DOT TMC
- Option 3: continue the system with the control procedures similar to what was utilized for the operational test, but with some of the DIVERT system elements eliminated

Option 1: Discontinue the system: Under this option all main diversion features of the system would be disconnected and the DIVERT project and services would cease. Some distinct elements of the system could stay in place (e.g., the surveillance cameras located on the arterial streets), but the incident detection and management features would no longer be provided.

Option 2: Continue the system with some/all control shifted to the Mn/DOT TMC: The main reason for considering this option is the limited hours that the City is able to provide for system coverage. The TMC is staffed from 6:00 a.m. to 9:00 p.m. on weekdays and eight hours a day on weekends. Therefore, by transferring either all DIVERT control or "after hours" DIVERT control to the TMC, the effective DIVERT service hours could be greatly expanded.

Option 3: Continue the system, but with some of the DIVERT system elements eliminated: Under this option key service elements of DIVERT would be provided (e.g., sign messages and diversion traffic signal timing plans), but other elements from the original concept (e.g., automatic incident detection) would be eliminated.

4.3 DISCUSSION OF OPTIONS

Option 1: Discontinue the system: The group agreed that there was no need to take this drastic step. Certain key features of the system (e.g., arterial blank out signs and the signal timing download module) work well and appear to be stable elements. Therefore, there is little risk in committing to maintaining those elements and thereby providing some amount of DIVERT service.

Option 2: Continue the system with some/all control shifted to the Mn/DOT TMC: This option would allow extended hours of operation for the DIVERT system. For the option to succeed, two major items would need to be accomplished, one technical and one institutional. First, from a technical point of view, the DIVERT system as designed and implemented only allows for access from the City Hall Annex and the City Dale Street Traffic Operations Shop. The system does not provide for or allow access from the TMC or from any other remote location. Therefore, a major technical effort would be required to modify the system to allow TMC access.

Second, from an institutional point of view, there is concern over the issue of who makes traffic control decisions that impact City of St. Paul streets. For the system to operate in "off hours" the TMC operators would need to be given the responsibility of making several key decisions, i.e., when to divert traffic onto City streets, which traffic signal plan to implement, how long to keep the plan on and what fine tuning steps to take while the plan was operating). The City of St. Paul felt that even if the TMC would agree to take on this effort, the City could not relinquish its traffic control responsibility for City streets. Although the traffic volumes in off-hours are typically lighter (and therefore "less critical") there still may be special events occurring or other conditions that would lead an experienced City operator to make certain control decisions. With the City's need to be liable for the traffic service and conditions on City streets, the City did not feel that it could forgo its own operation of the signals on City streets.

Option 3: Continue the system, but with some of the DIVERT system elements eliminated: Under this option, the team would desire to get the most "future benefit" out of the system for the least "future cost" (and effort). The key to this option is to continue using those elements that are successful and provide valuable service, while eliminating those elements that don't work as well and/or provide questionable value when working as designed.

The group determined that some of the DIVERT elements from the original concept that cause the most on-going maintenance and attention were not critical to providing the key DIVERT service elements.

The incident (or congestion) detection portion of DIVERT has proven to be an unstable element, whose benefit is questionable. As described elsewhere in this evaluation report, the DIVERT incident detection system needs to have a three step process work successfully to provide accurate congestion notification:

- the DIVERT computer in the TMC must get real time detector data from the TMC system, and the TMC detector coverage must be sufficient
- the real time data must be transmitted to the main DIVERT computer at the St. Paul City Hall Annex, and
- the incident detection algorithm must accurately detect proper congestion levels for operator notification

At the time of the meeting to decide the future of DIVERT, the detector link from the TMC had been down, and the City and TMC were already handling congestion or incident notification on a manual basis.

A second area of concern for long term operation is the set of portable changeable message signs. These have proven to be difficult to maintain on-line and, in addition, the signs require a significant amount of yearly maintenance when they are placed in a permanent roadside environment. (Most typically, these types of signs are used on a temporary basis and are not expected to stay in the field on a permanent basis.)

4.4 RECORD OF DECISION

The group decided to move forward with the third option presented above, "continue the system, but with some of the DIVERT system elements eliminated". The points enumerated below record the team's basis for making this decision.

Incident detection: The automated incident/congestion detection module was eliminated. As stated elsewhere in this evaluation report, throughout the project this has been a problematic element. The TMC advocated (and the rest of the team accepted) a traditional TMC incident detection process. The TMC representative stated that with the high percentage of drivers with cellular phones, when a major incident occurs, the TMC (via the State Patrol scanner) knows of the incident quite quickly and accurately and out-performs incident detection algorithms. Also, for verification the TMC uses the CCTV camera system to confirm the State Patrol information. With the agreed upon incident/congestion level that will trigger DIVERT implementation, it is expected that the TMC will "detect" DIVERT incidents very infrequently. Because the automated incident detection element was eliminated, the team decided to disconnect the personal computer that was in the TMC for use by DIVERT to collect and transfer TMC detector data. This computer will be returned to the OATS office.

Freeway Signing: The portable message signs were not meant as permanent elements. They were chosen because they could be readily implemented for the test, and because during the design phase of the project it appeared that in the future more overhead signing was going to be implemented in the DIVERT area through other Mn/DOT efforts. By the end of 1998, at three of the four DIVERT portable changeable message sign locations, new TMC overhead variable message signs will be implemented. These signs were or will be implemented as part of separate TMC efforts, and their locations give them synergy to the DIVERT project needs. For these three locations that team decided to port the messages from the portable signs to the TMC signs.

As of July 1998, the new TMC sign on eastbound I-94 had been implemented and the portable message sign was removed from the freeway. The two sites scheduled to be activated in the second half of 1998 are northbound I-35E and westbound I-94. For these signs, the TMC will cover all maintenance as part of their total freeway sign maintenance activities; there would be no charge to the DIVERT project or the City for that maintenance.

For the fourth DIVERT sign, southbound I-35E, the TMC does not have an overhead sign well placed to serve the DIVERT project, nor are there any firm plans now to have a sign in the DIVERT area. Even with no TMC sign to take over the function, the team still decided to remove the southbound I-35E portable sign, as no partner was interested or able to provide on-going maintenance for it. Therefore, no DIVERT message service will be provided for southbound I-35E traffic.

City control elements: The City of St. Paul will continue to operate all DIVERT elements on its right of way (e.g., CCTV cameras and arterial "blank out" signs). Also, the City will continue to run the DIVERT central processor that downloads new traffic signal timing plans.

Operations Plan: The team also agreed to a formal operations plan that will link the TMC incident detection, the freeway signing and the City response elements. When the TMC operator becomes aware of a "major" incident or congestion in the DIVERT area, the TMC operator - as part of their standard work scope for major incidents - will call the St. Paul operator. With the agreed upon description of the threshold for when DIVERT would be activated, the team's expectation is that DIVERT would only be turned on a few times a year. Therefore, the TMC incident notification process would also only be invoked very infrequently. To facilitate receiving the TMC calls when they do occur, the City agreed to keep two pagers active for City operators, at City expense.

When the City operator receives the notification the City and TMC operators will further assess the situation and the City operator will make the ultimate decision regarding DIVERT activation. If the City operator decides to activate DIVERT, the City operator will select the desired message and ask the TMC operator (who physically controls the sign) to turn on the message. In this manner, the City of St. Paul maintains decision control over the activation of diversion messages.

Along with the freeway diversion messages the City operator will activate the special DIVERT signal timing plans and arterial based blank out signs.

At the end of the incident management period the City operator will call the TMC and request that the TMC operator turns off the diversion message on the overhead freeway sign. At the same time the City operator will return the city controlled elements to their off condition.

Maintenance: Mn/DOT TMC will maintain the freeway element of DIVERT Legacy (the variable message signs) as part of their system-wide freeway sign maintenance program. The City will maintain the DIVERT Legacy components on City right of way or in their possession.

With the agreed upon actions described above, the major service elements of DIVERT (i.e., incident management through signing and signal control) will remain in place for three of the original four freeway directions. Although some elements such as the automated incident detection system and expert system control approach, have been eliminated, the core objective of the project, which is to better manage traffic through and around the Capitol Area Interchange during incidents, will remain for the three implemented directions.

5.0 CONCLUSION

The DIVERT system was conceived as an experimental project aimed at providing incident management services in the St. Paul Capitol Interchange area. The project represented an important agency partnership between Mn/DOT and the City of St. Paul, as both agencies worked cooperatively to develop the concept and operate the system. This was the first Mn/DOT-St. Paul effort to jointly manage traffic in the City of St. Paul. As an experimental and developmental project with ambitious goals, DIVERT faced a number of technical and management challenges. Over the course of the project, the timelines and expected work effort extended greatly. Ultimately, however, the important project challenges were met and the team members produced a stable, well functioning system.

DIVERT represents a successful ITS operational test. At the end of the test period the project partners decided to continue DIVERT as an ongoing, legacy system deployment fully supported by the Mn/DOT Traffic Management Center and the City of St. Paul. DIVERT Legacy provides the TMC with an important system to help it manage congested freeway flows during major incident events and it also provides the TMC with a new level of institutional cooperation between it and the City. For the City, DIVERT Legacy provides a set of expanded management tools. These tools include arterial based CCTV cameras, arterial based signs, 17 special signal timing plans, the computer systems to operate the cameras, signs and timing plans and the enhanced communications with the TMC. With these expanded tools the City is better equipped to manage arterial traffic during incidents, special events and normal traffic flow periods. The City has already used these resources a number of times to manage City traffic needs in non-incident times. The benefits of DIVERT will continue to accrue to both operating agencies for many years into the future.

6.0 ACKNOWLEDGMENTS

In addition to the project partners and formal team members, other individuals also contributed significantly to the success of the DIVERT project. Special recognition is extended to two organizations and their key participants for their help in enhancing the DIVERT project.

- ADDCO, Inc. played a major role in ensuring the success of a key component of the system, the portable message signs on the freeways. ADDCO responded to a purchase specification and was a supplier to the project. When there was an apparent incompatibility issue between the sign modem equipment specified and the integration of this equipment into the DIVERT system, ADDCO spent a significant amount of personnel resources analyzing the situation. To solve the problems, ADDCO furnished and installed a specialized antennae on one sign unit and changed out modems on all four signs. This was done at no additional cost to the project and ensured a dependable communications system to the signs. The key ADDCO participants in this process were the company president Tim Nicholson, who authorized the additional work, and Dave Woosley who worked on solving the technical aspects of the situation.

- MLB Consultants was retained by the Mn/DOT Office of Advanced Transportation Systems to develop and install an office-wide project management system. While completing that office-wide assignment, Mike Lane of MLB also integrated DIVERT into the new project management system. Mr. Lane applied a considerable effort to pull together project records and establish a base for ongoing management activities. His effort played a significant role in the management process used to complete the project.

APPENDICES

A. CHRONOLOGY OF MAJOR EVENTS

B. DIVERT ACTIVATIONS, RECORD OF ACTIONS

C. RECORD OF MAJOR PROJECT DOCUMENTS

D. RESPONDENTS TO AGENCY QUESTIONNAIRES

E. DIVERT FAILURE LOG (sample raw data print-out)

APPENDIX A

DIVERT CHRONOLOGY OF MAJOR EVENTS

3rd Quarter 1993	The initial project concept is developed by the Mn/DOT Guidestar office and the City of St. Paul Department of Public Works Traffic Division. The project is named the "St. Paul Incident Management" or SPIM project. Ping Yi of Guidestar is assigned as Project Manager.
3rd Quarter 1993	Edwards and Kelcey, Inc., is selected as project engineering consultant to develop the project concept document and preliminary design.
3rd Quarter 1993	SafeTran Traffic Systems, Inc., is selected as a project private partner with the intent of demonstrating advanced traffic control operations with an on-street open architecture controller.
September 1993	Westwood Professional Services, Inc., is selected as project independent evaluator to develop the evaluation plan.
July 1994	The draft Concept Definition Report is completed. Preliminary design activities begin.
August 1994	Project manager Ping Yi leaves Mn/DOT and is replaced by Sam Boyd of the Mn/DOT Guidestar office.
September 1994	The Evaluation Plan Document is completed. Work begins on Detailed Evaluation Plan.
December 1994	The role of Edwards and Kelcey is expanded from project designer to include system software development and limited system integration.
1st Quarter 1995	Project name is changed to "During Incidents Vehicles Exit to Reduce Time" or DIVERT.
3rd Quarter 1995	Procurement activities are conducted for major system field components (CCTV cameras and poles, portable changeable message signs and arterial "blank out" signs).
January 1996	Detailed Evaluation Plan is completed.
February 1996	Project kick-off event is held for DIVERT and St. Paul Advanced Parking Project; scheduled DIVERT start-up is set for February 29, 1996.

DIVERT CHRONOLOGY OF MAJOR EVENTS, cont'd.

1st Quarter - 4th Quarter 1996	Formal start-up date is suspended; system debugging and integration efforts continue.
November 1996	Project Manager Sam Boyd leaves Mn/DOT; no immediate replacement is named.
December 9, 1996	System is certified to be used for project, operational test period begins and evaluation data collection commences.
December 10, 1996	Edwards and Kelcey formally recognized and named as a DIVERT contributing private partner.
April 1997	Ben Osemenam of Guidestar office is named project manager.
April 2, 1997	DIVERT system is activated for full incident management service (Activation Number 1; Duration 28 minutes).
May 23, 1997	DIVERT system is activated for full incident management service (Activation Number 2; Duration 15 minutes).
2nd Quarter - 3rd Quarter 1997	Congestion notification thresholds are calibrated and adjusted to better meet agency expectations on level of pager notifications.
3rd Quarter 1997	Modems are changed on portable changeable message signs to ensure more stable system operation.
October 1997	Decision is made to extend evaluation data collection period to June 30, 1998.
October 13, 1997	DIVERT system is activated for full incident management service (Activation Number 3; Duration 2 hours, 16 minutes).
December 1997	Final Design Report and Operations Manuals are delivered; Edwards and Kelcey completes its project involvement.
June 30, 1998	Formal evaluation data collection period ends.
July 14, 1998	Project Management Team decides future of DIVERT system operation after end of operational test period.
August 1998	Evaluation Report is published.

APPENDIX B

DIVERT ACTIVATION NUMBER 1
April 2, 1997
Duration of Incident Management Control: 28 Minutes

Record of Actions for Activation Number 1
• St. Paul DIVERT operator noticed congestion and emergency vehicles on monitor for westbound I-94. • St. Paul operator called TMC and reached agreement on DIVERT activation. The system was activated at 7:23 a.m. • Automatic data logging was not operational. • St. Paul operator visually noticed more vehicles exiting to Kellogg Boulevard, but noted no unique traffic problems along Kellogg Boulevard. • The intersection of Kellogg Boulevard and Robert Street experienced high delays because of the closure of the nearby Wabasha Street bridge. (This occurred on a routine basis throughout the Wabasha Street Bridge construction period.) The DIVERT operator released this intersection from coordination to alleviate the Robert Street delays. • When traffic volumes on I-94 returned to normal levels, the system was turned off at 7:51 a.m.

DIVERT ACTIVATION NUMBER 2
May 23, 1997
Duration of Incident Management Control: 15 Minutes

Record of Actions for Activation Number 2
• TMC operator noticed an accident on westbound I-94 near junction of westbound I-94 and southbound I-35E during the p.m. peak period. • TMC operator called St. Paul DIVERT operator and the two operators agreed to activate DIVERT. • Automatic data logging was not operational. • Accident was fairly minor and was in the non-peak direction for the p.m. period. St. Paul operator visually noticed that only a small amount of vehicles diverted and that the freeway congestion cleared rapidly. • Fifteen minutes after activation, the system was turned off.

DIVERT ACTIVATION NUMBER 3
October 13, 1997
Duration of Incident Management Control: 2 Hours, 16 Minutes

Record of Actions for Activation Number 3
• At 11:05 a.m., an accident involving a freight truck occurred on eastbound I-94 near the Lafayette Bridge. Cargo fell off a truck and blocked the freeway. A large backup immediately started forming and the TMC operator called the DIVERT operator. • For approximately 15 minutes, all three lanes of eastbound I-94 were blocked and queues grew substantially. By 12:00 noon, two lanes remained blocked, but traffic was being directed through the area on one remaining lane plus the shoulder. • The DIVERT system had recently undergone some software revisions and was not working properly. The DIVERT operator was unable to use the system in its regular configuration to activate a diversion plan. • The DIVERT operator contacted the system developer's lead software engineer and, working together by phone, the two parties were able to activate DIVERT elements at 12:05 p.m. through a cumbersome, "work-around" process. • Automatic data logging was not operational. • Visual observations by the DIVERT operator and field checks by St. Paul personnel indicated that only a small percentage of vehicles diverted. • At 2:21 p.m., the roadway blockage was cleared, the traffic backup had dissipated and the DIVERT system was turned off.

APPENDIX C

DIVERT PROJECT
Record of Major Project Documents

Document	Date	Author
Project Management Materials:		
• Project Management Team Meeting Minutes	1994-1998	Various Team Members
Design Documents:		
• Concept Definition and Preliminary System Design	July 1994	Edwards and Kelcey
• Summary Report/Detailed System Design	November 1997	Edwards and Kelcey
Operations Documents:		
• DIVERT Operations Manual	December 1997	Edwards and Kelcey
• DIVERT Operator's Guide	December 1997	Edwards and Kelcey
Procurement Specifications:		
• Blank-out Signs Specification	1995	Edwards and Kelcey / Mn/DOT
• Portable Changeable Message Signs Specification	1995	Edwards and Kelcey / Mn/DOT
• Closed Circuit TV Cameras Specification	1995	Edwards and Kelcey / Mn/DOT
Legal Agreements:		
• Mn/DOT - City of St. Paul Partnership Agreement	1995	Mn/DOT
Marketing Materials:		
• Project Kick-off Promotional Materials	February 1996	Mn/DOT
Evaluation Documents:		
• SPIM Operational Test Evaluation Plan	January 1995	Westwood Professional Services
• DIVERT Detailed Evaluation Plan	January 1996	Westwood Professional Services
• DIVERT Evaluation Report	August 1998	Westwood Professional Services

Note: Original or record copies of these documents are maintained at the Mn/DOT OATS office.

APPENDIX D

DIVERT PROJECT
Respondents to Agency Questionnaires

Agency	Number of Respondents to:	
	Agency Administrator Questionnaires	Operator Questionnaires
Mn/DOT OATS Office	1	---
Mn/DOT Traffic Management Center	2 (1)	5 (2)
City of St. Paul	1	1

(1) Systems Operation Engineer and Incident Management Engineer
(2) Two control room operators and three control room information officers

Note: The agency administrator and operator questionnaires served as important input to the evaluations of several of the project elements. Because of the small number of respondents by agency, the respondents lose some of the anonymity preferred for survey respondents. In all cases, respondents answered the questionnaires knowing this condition.

APPENDIX E

DIVERT FAILURE LOG

Page No. 1
08/18/98

DIVERT

(System Component Failure Log)

DATE NOTICED	TIME NOTICED	TYPE	FAILURE	TIME OF NOTIFICATION	ACTION TAKEN TO REPAIR FAILURE	DATE OF REPAIR	TIME OF REPAIR	EFFECT OF FAILURE ON OPERATIONAL TEST
12/09/96	09:00	HS	No Comm to VMS #3	11:30	Repaired (ADDCO)	12/09/96	13:00	None
12/09/96	13:00	S	VMS Icon Bug	13:00	Debugged (E&K)	12/09/96	14:00	None
12/09/96	14:00	H	Kellogg/7th Cntroller Hit	14:00	Contr Replaced (C.Forces)	12/10/96	15:00	None
12/16/96	09:30	HS	No Comm to VMS #3	09:30	Repaired (ADDCO)	12/16/96	11:00	None
12/17/96	08:00	HS	No Comm to VMS #3	08:00	Repaired (ADDCO)	12/18/96	07:30	None
12/17/96	08:15	HS	TMC Detectors Failed	08:15	Repaired (TMC)	12/17/96	09:00	No Detection Possible
12/17/96	15:30	HS	No Comm to VMS #4	15:30	None (Cellphone Miscue)	12/18/96	10:00	None
12/19/96	07:30	HS	No Comm to VMS #3	08:00	Repaired (ADDCO)	12/19/96	14:00	None
12/26/96	08:00	H	CCTV #3 Picture Scrambled	08:00	Tuned (City Forces)	12/26/96	13:30	None
12/26/96	14:00	H	CCTV #'s 1,3 Fogged		None	12/27/96	07:00	None
12/26/96	14:00	H	CCTV #'s 1,3 Spotty		None	12/27/96	07:00	None
12/31/96	08:00	HS	No Comm to VMS #'s 1,3,4	08:00	Repaired (ADDCO)	01/02/97	14:00	None
01/02/97	11:15	S	TMC Detector Link Down	11:15	Rebooted (TMC)	01/03/97	07:00	No Detection Possible
01/06/97	07:30	HS	No Comm to VMS's	08:00	CHA Terminal Connections	01/06/97	09:00	None
01/06/96	08:00	HS	No Comm to VMS #3	08:15	Repaired (ADDCO)	01/15/97	08:00	None
01/06/97	13:30	HS	No Comm to VMS #2	13:30	CHA Terminal Connections	01/06/97	13:45	None
01/07/97	13:00	H	CCTV #'s 2,3 Fogged		None	01/07/96	14:30	None

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01/08/97 11:30  H  CCTV #3 Fogged                    None                        01/08/96
15:00             None
01/13/97 15:30  HS No Comm to VMS #1         15:30  Repaired (ADDCO)            01/15/97
08:00             None
01/15/97 08:00  HS No Comm to VMS #4         08:00  Repaired (ADDCO)            01/16/97
08:00             None
01/15/97 14:30  S  TMC Detectors Failed      14:30  Repaired (TMC)              01/15/97
15:30  No Detection Possible
01/16/97 07:30  S  'NO CURRENT RECORD'       08:00  Repaired (E&K)              04/28/97
17:00  Data Collection Suspended
01/16/97 15:45  S  TMC Detectors Failed      15:45  Repaired (TMC)              01/16/97
16:00  No Detection Possible
01/17/97 13:30  S  TMC Detectors Failed      13:30  Repaired (TMC)              01/17/97
14:00  No Detection Possible
01/27/97 11:30  S  TMC Detectors Failed      11:30  Repaired (TMC)              01/27/97
13:00  No Detection Possible
01/27/97 11:30  HS No Comm to VMS #2         12:00  Repaired (E&K)              02/19/97
12:30             None
01/27/97 14:30  H  CCTV #3 Fogged                    None                        01/27/97
07:30             None
01/27/97 14:30  H  CCTV #6 Spotty                    None                        01/27/97
07:30             None
01/29/97 09:30  O  VMS #2 Turned Parallel    10:00  Corrected ( MnDOT)           01/30/97
11:00             None
01/31/97 07:45  HS No Comm to VMS #4         08:15  Repaired (E&K)              02/19/97
12:30             None
02/03/97 07:30  HS No Comm to VMS #1         08:00  Repaired (E&K)              02/19/97
12:30             None
02/04/97 10:30  S  TMC Detectors Failed      10:30  Repaired (TMC)              01/07/97
07:30  No Detection Possible
02/06/97 14:00  H  CCTV's Spotty                    None                        01/07/97
07:30             None
02/10/97 07:15  HS No Comm to VMS #3         08:00  Repaired (E&K)              02/19/97
12:30             None
02/18/97 07:15  H  No Comm to MTCS Line 16   07:30  Relay Replaced (City)       02/18/97
14:00             None
02/24/97 07:30  HS No Comm to VMS #2         08:00  Manual (DIVERT Menu)        02/24/97
07:35             None
02/24/97 07:30  H  No Comm to VMS #3         08:00  Antenna Relocated (ADDCO)   03/10/97
14:00             None
02/24/97 15:45  H  CCTV's 3,6 Spotty                 None                          /  /
02/26/97 07:15  HS No Comm to VMS #1         08:00  Repaired (ADDCO)            02/28/97
13:00             None
03/07/97 12:30  H  VMS #2 Reported Hit       13:00  None                          /  /
03/12/97 11:30  HS No Comm to VMS #4         11:30  Repaired (ADDCO)            03/17/97
15:30             None
03/14/97 14:30  S  Event Log (divert.mdb)    15:00  Repaired (E&K)              04/27/97
16:00             None
03/19/97 08:00  HS No Comm to VMS #3         08:15  Repaired (ADDCO)            03/19/97
11:30             None
03/20/97 12:30  S  No TMC Detector Comm/Data 12:35  Repaired (TMC)              03/26/97
10:00             None
03/24/97 07:30  HS No Comm to VMS #2         08:30  Repaired (ADDCO)            03/27/97
15:30             None
03/31/97 10:00  S  No Data From TMC          11:00  Repaired (TMC)              04/01/97
11:20             None
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DIVERT FAILURE LOG, cont'd.

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DIVERT
(System Component Failure Log)

DATE TIME NOTICED	TIME NOTICED	TYPE	FAILURE	TIME OF NOTIFICATION	ACTION TAKEN TO REPAIR	DATE OF FAILURE REPAIR	TIME OF REPAIR	EFFECT ON OPERATIONAL TEST
04/01/97	07:30	HS	No Comm to VMS #3	08:00	Repaired (TMC)	04/04/97	10:30	None
04/03/97	13:30	HS	No Comm to VMS #1	13:45	Repaired (TMC)	04/04/97	15:30	None
04/07/97	08:00	HO	No Comm/Data From TMC	08:15	Repaired (City)	04/15/97	11:00	None
04/07/97	07:45	HS	No Comm to VMS #3	08:05	Repaired (ADDCO)	04/23/97	13:00	None
04/10/97	16:30	HS	No Comm to VMS #'s 1,4	16:30	Repaired (ADDCO)	04/11/97	07:00	None
04/16/97	09:30	H	VMS #2 Flickering	09:45	Repaired (ADDCO)	04/18/97	06:30	Flickering but Readable
04/16/97	08:15	HS	No Comm to VMS #2	08:30	Repaired (E&K)	04/21/97	14:00	None
04/22/97	07:30	HS	No Comm to VMS #4	08:30	Repaired (ADDCO)	04/28/97	14:00	None
04/23/97	08:30	HS	No Comm to VMS #1	08:45	Repaired (City)	04/30/97	08:00	None
04/28/97	07:45	S	Date/Time Won't Download	09:30	Repaired (E & K)	04/29/97	16:00	None
04/29/97	15:00	S	Backround Data Collection	15:30	Debugged (E & K)	04/29/97	16:00	None
05/09/97	07:15	HS	TMC Detectors Failed (70)	07:30	Repaired (TMC)	05/09/97	09:30	None
05/12/97	07:45	HS	No Comm to VMS #3	08:00	Repaired (City)	05/12/97	09:00	None
05/13/97	07:30	HS	No Comm/Data From TMC	08:00	Repaired (TMC)	05/13/97	08:15	None
05/15/97	09:45	HS	No Comm/Data From TMC	10:00	Repaired (TMC)	05/15/97	10:30	None
05/19/97	07:30	HS	No Comm to VMS #3	08:00	Repaired (City)	05/20/97	14:00	None
05/21/97	08:00	HS	TMC Detectors Failed(50%)	08:15	Repaired (TMC)	05/21/97	08:30	None
05/23/97	13:00	HS	No Comm to VMS #4	14:30	Repaired (ADDCO)	05/23/97	15:00	None

06/02/97 07:45 HS No Comm to VMS #3 08:00 Repaired (ADDCO) 06/09/97 12:00 None
06/09/97 07:30 S Server Down 07:45 Rebooted (City) 06/09/97 08:00 None
06/09/97 07:45 HS No Comm to VMS #1 08:00 Restarted (ADDCO) 07/03/97 08:30 None
06/12/97 07:45 HS No Comm to VMS #3 08:00 Repaired (ADDCO/City) 06/16/97 09:30 None
06/17/97 07:30 HS No Comm to VMS #3 08:00 Repaired (E & K) 06/27/97 11:00 None
06/17/97 07:30 HS No Comm to VMS #4 08:00 Restarted (City) 08/12/97 13:00 None
06/18/97 07:30 S Server Down 07:45 Rebooted (City) 06/18/97 08:00 None
06/27/97 11:00 HS TMC Detectors Failed 11:15 Rebooted (TMC) 06/27/97 11:30 None
06/30/97 07:30 S Workstation Time Wrong 07:30 Corrected (City) 06/30/97 07:35 Event/BDC Logs Suspended
06/30/97 07:30 HS TMC Detectors Failed 07:45 Re-Booted (TMC) 07/14/97 12:00 None
07/02/97 15:00 HS No Comm to VMS #1 15:15 Restarted (City) 07/02/97 18:30 None
07/03/97 11:30 HS No Comm to VMS #3 13:00 Restarted (E & K) 07/08/97 07:00 None
07/06/97 14:00 HS No Comm to VMS #2 Restarted (City) 08/12/97 13:00 None
07/14/97 08:00 HS No Comm/Data From TMC 08:30 Rebooted (TMC) 07/14/97 09:00 None
07/18/97 17:00 HS Server Down Rebooted (City) 07/21/97 13:00 None
07/25/97 08:30 HS No Comm to VMS #3 09:00 Restarted (E & K) 07/25/97 14:30 None
07/28/97 08:00 S TMC Detectors Failed 08:30 Rebooted (TMC) 07/28/97 09:00 None
07/30/97 08:00 HS No TMC Comm/Data 09:00 Rebooted (TMC) 07/30/97 09:30 None
08/04/97 08:15 HS No TMC Comm/Data 08:30 Comm Protocol Reset(City) 08/22/97 11:30 None
08/04/97 08:15 HS No Comm to VMS #3 08:30 Restarted (City) 08/12/97 13:00 None
08/11/97 08:15 HS No Comm to VMS #1 08:30 Restarted (City) 08/12/97 13:00 None
08/13/97 08:00 HS No Comm to VMS #2 08:00 Restarted (City) 08/13/97 11:30 None
08/28/97 12:00 HS No Comm to VMS #3 12:00 Restored(Modem Connected) 10/22/97 07:45 None
09/01/97 12:00 HS Kell/35 Blankout Flashing 09:00 None 09/02/97 08:00 None
09/03/97 15:15 H CCTV #4 Won't Tilt 15:15 Repaired (City) 10/01/97 12:00 None
09/04/97 14:00 HS No TMC Comm/Data 14:15 Rebooted (TMC) 09/05/97 13:15 None
09/05/97 08:30 H CCTV #3 Down 08:30 Repaired (City) 02/04/98 09:00 None
09/09/97 08:30 HS No TMC Comm/Data 08:30 Rebooted (TMC) 09/15/97 08:00 None

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(System Component Failure Log)

DATE TIME NOTICED	TIME NOTICED	TYPE	FAILURE	TIME OF NOTIFICATION	ACTION TAKEN TO REPAIR FAILURE	DATE OF REPAIR	TIME OF REPAIR	EFFECT OF FAILURE ON OPERATIONAL TEST
09/09/97	10:15	HS	No Comm to VMS #4	10:15	Repaired (US West)	11/17/97	10:30	None
09/18/97	14:00	HS	No TMC Comm/Data	14:15	Rebooted (TMC)	09/18/97	14:30	None
09/19/97	08:00	HS	No Comm to VMS #2	08:00	Debugged (E&K)	10/14/97	09:15	None
09/25/97	14:30	HS	No Comm to VMS #1	14:30	Repaired (US West)	11/17/97	10:30	None
09/25/97	14:30	HS	No Comm to VMS #3	14:30	Repaired (US West)	11/17/97	10:30	None
09/29/97	08:00	HS	No TMC Comm/Data	08:15	Rebooted (TMC)	09/29/97	08:20	None
10/13/97	12:00	S	Could Not Start Scenerio	12:15	Debugged (E&K)	10/13/97	16:00	Scenerio Manually Started
10/15/97	14:30	HS	VMS Dial-Up Line Bad	15:00	Repaired (US West)	11/17/97	10:30	None
10/16/97	10:30	HS	No Comm to VMS #2	10:30	Repaired (US West)	11/17/97	10:30	None
10/24/97	08:00	S	No TMC Comm/Data	08:15	Repaired (E & K)	12/08/97	11:00	None
11/21/97	08:00	S	VMS #4 Display Error	13:30	Rebooted (City)	11/21/97	14:30	Bogus Info to Motorists
12/01/97	07:30	S	VMS #4 Display Error	08:00	Database Restored (E & K)	12/09/97	14:30	Bogus Info to Motorists
12/08/97	09:30	HS	No Comm to VMS #3	09:30	Rebooted (City)	12/08/97	11:00	None
12/10/97	13:15	HS	No TMC Comm/Data	13:30	Repaired (TMC)	12/10/97	15:00	None
12/22/97	14:00	S	Workstation Program Crash	14:15	Repair Event.mdb (City)	12/23/97	10:00	None
12/29/97	08:00	HS	No TMC Data	08:15	Rebooted (TMC)	12/29/97	15:30	None
01/16/98	08:00	H	CCTV #1 Auto Iris	08:15	Repaired (City)	01/23/98	10:00	None
03/11/98	08:00	S	VMS #1 (Blinking)	08:15	Repaired (City)	03/11/98	08:15	None

03/12/98 09:15	S	VMS #1 (Blinking)	09:30	Rebooted (City)	03/12/98 10:30
None					
03/16/98 07:30	S	VMS #1 (Blinking)	08:00	Shut Down (City)	03/16/98 08:00
None					
03/26/98 07:45	HS	No TMC Comm/Data	08:00	Repaired (TMC)	03/26/98 08:30
None					
05/05/98 08:00	HS	No TMC Comm/Data	08:15		/ /
05/11/98 08:00	H	CCTV #6 Unstable Picture	08:15	Repaired (City)	06/05/98 15:30
None					
05/20/98 08:00	H	CCTV #1 No Picture	08:30		/ /
05/28/98 08:00	H	CCTV #4 Scrambled Picture	08:15	Repaired (City)	06/05/98 15:30
None					
05/29/98 08:00	H	CCTV #3 No Tilt/Pan/Zoom	08:30	Repaired (City)	06/05/98 15:30
None					
06/24/98 08:00	HS	VMS#2 Display On (Eratic)	08:15	Repaired (City)	06/24/98 09:30
None					